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AMONGST MACHINES

By the Author of "The Young Mechanic"

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AMONGST MACHINES

A

DESCRIPTION OF VARIOUS MECHANICAL APPLIANCES
USED IN THE MANUFACTURE OF WOOD, METAL,
AND OTHER SUBSTANCES.

A Book for Boys

COPIOUSLY ILLUSTRATED

BY THE AUTHOR OF

"*THE YOUNG MECHANIC*" James Lurkin

NEW YORK
G. P. PUTNAM'S SONS
182 FIFTH AVENUE
1877

PREFACE.

SOME time has now elapsed since the publication of "The Young Mechanic," but when that book was issued, it was intended to supplement it by some such volume as that now placed before our young friends. Although designed and especially written for the perusal of boys, it is possible that it may convey interest and instruction to some of maturer years, as all ought to have some knowledge of the processes and means used in the production of articles of daily use. "How was it made?" seems a very natural question for one to ask who takes up any production of our various industries, and it is for the purpose of giving a reply to such a query that we have penned the present volume. Of course, in a small, and of necessity somewhat sketchy book like the present, there is much remaining untold which would be full of

interest to the reader; but, so far as our limits would allow, we have endeavoured to give sufficient detail to make each subject treated clear and easy of apprehension. Of some machines and processes we have written at full length; of others we have laid down the principle of construction, as being common to many others of the same class, and have not described the actual details of any one in particular. Thus we have endeavoured to instruct the reader in those fundamental laws which of necessity underlie the system of machinery, and upon which are founded the various mechanical combinations which have contributed so much to the development of our manufactures. Very many hand processes which prevailed only a few years ago, are fast disappearing in spite of prejudice and vested interests, which make the introduction of machine-work so hazardous and speculative to the manufacturer; and as the demand for certain necessaries of civilised life, once confined to the richer classes, is now extending more widely every day, it becomes absolutely necessary to use mechanical appliances to increase as well as to cheapen the supply by hastening the various processes of production. Thus from year to year we meet with new machines or improvements upon

those already in use, and there is good reason to suppose that the increased wages now demanded by labourers of all classes will call into action more than ever the inventive faculty and energy of our manufacturers and employers. Hence it has appeared to us a very fit time to instruct the younger portion of the community in the details of the more ordinary machines, with which they may perhaps some day become closely and personally interested. Those used for the production of textile fabrics, however, we have been unable to treat of in the present volume, as they need more space than we have at our command, as well as a large number of drawings to make the details of their construction clear. Possibly this may occupy our attention at some future time, but for the present we can only hope that the book now in the reader's hands may prove useful and interesting, and make our boys thirst for further information, which ought, we consider, to be the effect of all such outlines of instruction as these little volumes are intended to impart.

J. L.

STETCHWORTH, *July* 1876.

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AMONGST MACHINES.

INTRODUCTORY.

"De gustibus non disputandum."
"Chacun à son goût."

NOW, boys, out with your dictionaries, if you need them, and translate the above mottoes of an old friend, who has made up his mind to write another little volume for your special delectation. In my last I told *you* "how to make;" I now propose to tell you what *others* have made, and what, in fact, they are making every day, for the use of their fellow-creatures. Accustomed as we are in these days to the luxuries of life, we have little idea that a very few years ago these luxuries were almost unknown, and that what we should now designate the necessaries of life, our ancestors would have rather despised as effeminate indulgences, unworthy of their attention. How we should cry

out at floors without carpets, and even without boards, thinly strewed with a covering of fresh rushes, cut amid the swamps and marshes; yet time was when these constituted the carpets of princes and kings alone, and, even in palaces, were not unfrequently found wanting, except in the state apartments. And as to soft feather beds and spring mattresses, and luxurious pillows, arranged upon luxurious and handsome bedsteads, it was not even in the power of the rich to obtain them. As for the poor, a heap of straw, or of leaves, not always too fresh or too dry, formed the only resting-place after days of labour such as are now happily unknown. The truth is, we have during the last fifty years made such gigantic strides in civilisation that each class has stepped into the position of those above them. The smock-frock and humble gig of the thriving farmer have given place to the fashionable suit and waggonette; the old-fashioned plain tradesman has become "Esquire;" and the stage-coach, with its well-bred team of roadsters, has disappeared before that snorting iron steed that was once known, when a comparative colt, as Stephenson's "Puffing Billy." In 1830, steam locomotion was in its infancy; in 1875, it has, we may fairly say, wellnigh reached its climax, and in all probability the engine as it now stands will not undergo any material alteration, although it is to be hoped that railway *management* will mightily improve,

and means be provided for increasing both the comfort and safety of travellers. It is to the general introduction of steam-machinery that we are, indeed, indebted for the rapid advance and improvement of all nations into which it has penetrated. The native Hindoo may seem to beat us in the fineness of his textile fabrics; and the hand-looms of the East may send forth rugs and carpets which ravish the eye with their rich and harmonious colours, but the quantity thus produced is utterly insignificant; and hence these costly and tedious results of native skill can never come into general use, nor compete with the products of our steam-looms and gigantic carpet manufactories. Then, again, look at our works in metal. Here we have absolutely first created a want, and then devised the means of supplying it. What did our ancestors require in the way of writing materials? Not one in ten could write their own names fifty or sixty years ago, and a few quills plucked annually from the wretched geese in the Lincolnshire fens amply sufficed the needs of the last generation. *Now* we think nothing of rolling a few hundred tons of steel into a few thousand gross of steel pens; yet, so vast and ceaseless is the demand, that every day, and all day long, does the unrelenting machinery groan and toil at its heavy task. At times it appears as if every possible requirement of humanity must needs be satisfied. "Having food and

clothing," it would be imagined that we might "be content;" but all at once a new demand arises, we hardly know how, and as it increases, it brings other requirements in its train; and new machines are planned, and new and gigantic manufactures spring up, until people begin to wonder how it was possible to live and be happy without that particular article which, from being absolutely unknown and undesired, has at last become one of the necessaries of civilised life. Well do I remember, when a boy myself, the eightpenny letter, that had come but forty miles at most, brought in one of what then appeared plethoric bags carried by the venerable mail-coach—precious letter, indeed, in those days of high postal rates, when these delightful home messages were, like angel visits, few and far between. Then we thought forty and fifty miles a day a very fair journey for letters or for ourselves, and the London "Optimus," or "Highflyer," or "Express," was in our admiring eyes the *beau ideal* of rapid locomotion; yet even then these "old things were passing away," and by the time our jackets had been supplanted by the much-longed-for tailcoats, and the turn-down collars had given place to "stick ups" and cravats (which, by the way, were well denominated "chokers"), stage-coaches and mails were on their last legs, and visions were beginning to arise of iron horses and fast trains, cheap postage and electric tele-

graphs. *Now* the vision is realised, and we can only ask, "What is to come next?" The strangest fact connected with all this is the suddenness with which a new manufacture or industry springs up. When a thing actually exists as an everyday article of traffic, the popular mind seldom busies itself with the question of "how it came to pass;" there it is, and its presence is accepted as *un fait accompli.* Not so the thoughtful looker-on. A few years ago an industry existed in Manchester which is already on the wane. Thousands of tons of steel were being rapidly converted into long, flat, ribbon-like strips of varied width, but otherwise wonderfully alike. Coil upon coil was rolled out and tempered, and packed for home consumption and for export. It was crinoline steel for our wives and daughters! Fashion had decreed that the Elizabethan pattern should revive; and all at once, as it seemed, the new demand was met and satisfied, and more than one large fortune was made in carrying out this new and unlooked-for manufacture. But some one discovered that the steel cut through the fabric in which it was inserted, in spite of the care taken to obliterate the sharpness of its edges. At once manufacturing enterprise was turned in the new direction, and I know of one at least who realised a fortune by the invention of a machine for covering steel ribbons with a woven sheath of wool or cotton. In neither case was

the manufacture itself absolutely new, but it gave a new direction to, and created special modifications of, old inventions, and thus practically resulted in new and extensive industrial pursuits. It is in this way that there is a constant market for labour. One manufacture dies out when its products are no longer suitable to the peculiar demands of the times, and hundreds of hands, it would be supposed, must be thrown out of work; but instead of this, some real or imaginary want, or some unlooked-for fashion or custom, arises, and as one manufacture is gradually withdrawn, another takes its place, and needs the hands or the brains that would otherwise have been driven to forced idleness. It is most astonishing to mark the even poise of the scales between demand and supply, which again in turn regulates the market price of each commodity; and although it must now and then happen that individual hardship occurs, and from some unlooked-for and unexpected stagnation in trade, hands are thrown out of work who do not deserve that fate, it generally happens that there is a fair field of labour, and fair remuneration, for those who have the necessary qualifications of honesty and diligence. Most certainly these are days in which both the literal "slow-coach" and its moral representative have no place; even the stanch old Tory finds himself dragged unwillingly along, until he generally lands at least among the ranks of Liberal

Conservatism, if he does not go yet one little step farther; and both nations and people (even lethargic John Bull) find sometimes that they have taken a pretty long march before they were aware of it. Our go-ahead cousins, perhaps, have done not a little to wake us up in this respect. A vast number of improvements in our various industries hail from America, and for machinery to expedite certain manufactures there can be no question that we are considerably indebted to the cousins aforesaid. Probably we are more fettered by our patent laws than we are fully aware of. No man can realise the fruit of his head and hand work in England without very heavy expense, to which he is most probably quite unequal. Knowing this, many really clever workmen are afraid to turn their attention to the production of novel machines. They consider that the offspring of their own heavily-worked brains will only enrich others and impoverish themselves, and thus the very laws which ought to stimulate and encourage inventions do, in fact, restrain the exercise of talent and industry, and cramp and fetter mechanical craftsmen. The necessary result of this imperfection of our patent laws is, that other nations give us the go by, crib our inventions, and sell them back to us at a very considerable profit. As I am, however, addressing my old friends "the boys," I think it may be well to explain the nature of a patent, although I am

well aware that many of my readers are "up," as they say, "in that kind of thing," and know already something about patents. Well, all I can say is, if some do, some do *not;* so here goes, all the same, and the wiser and more knowing may skip the paragraph if they please.

Perhaps, as I sit over the fire thinking of things in general and mechanics in particular, a bright idea strikes me. Perhaps it is a machine for grinding up moons to make stars, or grinding up old people and making them into small boys; of course the idea is grand—it is noble—it is wonderful! it will make me a millionaire! and I begin to build castles, keep carriages, and become a man very mighty in my generation! That night I get no sleep, or if I do, visions of little old men and big old men greet me, popping head foremost into a huge coffee-mill, and coming out young rascals in jackets and knickerbockers. At early dawn I rise unrefreshed, seize pencil and compasses and ruler, and proceed to develop on paper the gigantic invention of my enlightened brain. Now, some ideas look very well as long as they are not thus delineated in cruel unrelenting black and white, and some will stand even this ordeal. Of course my grand mill will look really splendid on paper; so I make the rough sketch of its hopper, and stones, and bone-crushers, and sifters, and renovators; and then I draw them with

rule and compass, and ink them in, and it is done—triumph of brain over matter—and I must get a patent.

Searching the columns of the newspaper, I see the very advertisement I require, "Patents for inventions obtained, and successful sale ensured. Address Diddle-um & Do-em, Vanity Fair, near the Library of the Hocus-pocus and Gammon Institute." I cannot trust my precious invention to the custody of H.M. Post Office officials, I am off to London with my drawing in hand. I find the local habitation and name of the agents, and am introduced to the gentlemen themselves, who at once declare the thing perfect in all its details, request £10 or so on account, to secure the provisional protection or registration, which will secure the invention for a few weeks and prevent others from pirating it; and at length I depart full of hope by the evening train, and having duly arrived, add several more decorations and luxuries to my aërial castle. After some days I receive a note from the agents, "they have searched the records at the Patent Office, and have to congratulate me on the fact that no specification of such a machine as mine can be found; the very idea is novel, the details perfection, and strongly they would advise proceeding at as early a date as possible to complete the patent." This costs £100, with perhaps a few fees for search at the Patent Office, coloured drawings, stamps, and similar requisites. In the meantime the

invention is advertised, and I see my name in print as about to "proceed." I *do* proceed, and am opposed by another inventor who thinks or pretends to think he has forestalled me; of course litigation means more fees, but at last I triumph, and am duly acknowledged real and sole inventor and proprietor of the "Human Grinder." Now for results. No one will buy it from me. No manufacturer will undertake its construction and become my agent for its sale except at a price that will certainly remunerate *him*, but will never reimburse *me* the outlay already made; and, stranger still, though I have one made and placed in my own hall for inspection, not one old man—no, not even the oldest and most "faithful retainer" of the family—can be induced to take a header for the satisfaction of an inquiring but sceptical public. The whole concern has fallen flat upon the market, and I am left alone in my glory, pockets considerably lighter, heart so much heavier that I am almost tempted to take a header myself into the mill. Alas, boys! the climax is yet to come. My old addle-headed neighbour, taking the hint, but carefully avoiding the details of my machine, cribs the whole concern, reaps the produce of my sleepless nights and overworked brain, produces a precisely similar but not identical machine, patents it, grants licences to manufacture and use it, is eminently successful, amasses a fortune, and dies Sir Noodleton Addlehead. As for me,

I cut my—no, boys, not my throat just at present, but my "stick," and retire to a remote village to growl out my span of existence ingloriously. I *do* write sundry letters to the "Times" on the injustice of the patent law, which somehow or other fall into the editor's waste-paper basket. By this, boys, you see that the *object* of a patent is to secure all profits to an inventor for seven, ten, or fourteen years; the *result* of a patent is very frequently to impoverish the inventor and to enrich his neighbour. Now, if instead of this very heavy outlay, which of course always involves a risk of failure, an inventor could secure his patent for a pound or two, and be fairly certain that he would enjoy the proceeds of it, inventive faculty, even amongst our mechanical boys, would be considerably stimulated, and the regular workman would be encouraged to plan and contrive improvements which would first benefit himself, and next, in many instances, confer lasting benefit on his country. It is true that the Patent Office contains records of inventions quite as ridiculous and unmarketable as my imaginary human grinder, inventions which deserve their fate; but there are also many really clever and valuable discoveries utterly prevented from full development because the discoverers cannot find the funds to secure the patent, and do not choose to give away the creations of their own brains. It often happens, however, that some chance hint to a friend (?) better

provided with capital, or more happily situated, is seized, worked out, and made the subject of a successful patent, while the original inventor is obliged to plod along as before, unrecognised and unrewarded. It would not, perhaps, be very difficult for me to name more than one owner of a grand estate who has made a name and enriched his family by stealing the invention of the hard-worked and industrious mechanic. No one probably steps in to defend the right, and we all know how riches and power are wont to hush all inquiry as to how they have been gained. I speak of these things, my boys, on purpose to create in you a proper sense of justice, and to induce you to befriend the working men of your time. If fortune has or shall hereafter favour you, never think it a disgrace to take hold of that rough and sinewy right hand by whose work you obtain the various necessaries or luxuries of life; and if any of you live to become employers of labour, be careful to render to every one his due. Often among those hard sons of toil you will find the most noble Christian feelings, and often keen and active intelligence where you least suspect it. Unfortunately of late there has existed among labourers of all kinds a sense of injustice which has estranged them from their masters. The latter are not, however, always, nor perhaps generally in fault; yet in too many instances there has been real cause for complaint; and ill-feeling

once aroused, and fostered and kept up by unprincipled agitators (whose real object is to enrich themselves), has created a breach that it will require many years to stop. You, my boys, must be foremost to step into that breach when you come to manhood; and by your plucky defence of the right, and even-handed justice, you may do much to restore the good feeling and mutual dependence that once existed between the employers and the employed.

CHAPTER I.

HUMAN TOIL.

LABOUR and sorrow, toil and death, constitute the curse which has hung like a dark shadow over our world for about six thousand years. We know why that curse descended, and most of you, boys, know it too, and have in some degree partaken of it. But probably it has never struck you that the civilisation in which we pride ourselves—our arts and manufactures, our railways and telegraphs, and machinery of various kinds—is but the evidence of that curse, inasmuch as by these man is ever trying to lighten his labour and alleviate his toil. The muscles and sinews of the human frame soon grow weary, and yet our labour must not cease. Food and clothing are demanded by our frail and perishable bodies, and these wants must be supplied; and so the clever brain comes to the rescue, and devises, perpetually, new and improved modes of producing what we so urgently require—increasing and varying the manifold industries, by which the progress of

civilisation is ever marked. In the earlier ages of the world, man's wants were but few, especially while only the warmer regions of the earth were tenanted by the human race, and a redundant tropical vegetation made toil and labour a name rather than a reality.

The dispersion, however, that after the Flood commenced at Babel, soon compelled mankind to make for themselves homes in less genial countries, and to exert both mind and body to a much greater extent, in order to provide for the necessities of daily life. It is not necessary to trace man's progress from a condition of rude barbarism to a state of comparative civilisation, nor need we inquire at what date the "coats of skins," which at first sufficed for clothing, gave place to plaited or roughly-woven garments, of which we have specimens now existing among savage tribes of Indians and others. We may leap at once the intervening gulf of centuries, and speak of the arts and manufactures of later days.

We may, nevertheless, pause to note the fact that man, as suggested in our introductory chapter, creates his own wants, until what was once a *luxury* of life becomes a *necessity*, and what was at one time found only in "kings' houses" is demanded even in the cottages of the poor. It seems, in fact, less likely year by year that the time will come when we shall carry out with one accord the Apostolic maxim, "Having food and clothing,

let us be therewith content." It has, indeed, of late been a sore puzzle to the lawyers to decide, as they are sometimes called upon to do, what are to be considered the *luxuries* of life, and what the *necessaries.* Returning, however, to the primitive condition of mankind, we cannot be far wrong in considering food and clothing so absolutely necessary to his very existence that he must be a 'cute lawyer, indeed, who would venture to dispute the fact.

Now, simple as these are in themselves, neither would have been gained by sitting still. The fruits of earth must be obtained by culture; the flesh given to man for food must be procured by hunting; and then the food must be prepared in utensils more or less suited to the purpose. We therefore soon meet with other necessities—tools for the cultivation of the land, weapons for the chase, and means of cooking the food thus obtained.

The Book of Genesis, therefore, introduces us to such things at a very early date, and in the story there told us of the death of Isaac, we have mention not only of the quiver and the bow as ordinarily used for hunting, but also of venison made into savoury meat, betokening, at all events, a certain refinement in cooking to which the Patriarch was no stranger. At the same period we gather the fact that a clothing of the skins of wild beasts had been discarded for a lighter and more

convenient, as well as a more ornamental character of garment, Joseph's coat of many colours being, there is little doubt, made of some kind of woven material; and in the Book of Job, which some have supposed the oldest of all the sacred writings, the "weaver's shuttle" is mentioned as an article with which his readers or hearers were generally conversant. Implements and machines, more or less rude, but sufficing for the requirements of the times, were therefore almost of necessity invènted as soon as labour and toil were universally acknowledged to be the lot of man.

Vessels to contain water, and even to enable it to be boiled, as would soon be discovered, were provided by nature in the gourd and cocoa-nut, to which were added, as a more capacious reservoir, the skins of animals carefully removed from their carcases, and the various openings closed by tying or sewing. But these had at a very early date—partially, at all events—given way to articles of metal, so that we read of Tubal Cain some years before the Flood as a skilful artificer in brass and iron. These casual remarks of the sacred writers referring to the arts of civilisation, prove how very soon man, left to his own devices, learned to turn to his own use, for the purpose of increasing his comforts, the various mineral, animal, and vegetable products of the world around him. In carrying out the several processes

demanded for these purposes, he must have rapidly discovered the more prominent peculiarities of the materials placed in his hands, and we can but admire the talent which our progenitors evinced in overcoming such stupendous difficulties as smelting ores and refining the metals so obtained. From what we have been enabled to gather from native handicraft as still pursued in India and other Eastern nations, it would seem that the earliest works of the kind were produced by casting and by the use of the hammer. The heat of the fire was kept up by a pair of bellows made of goat or other skins, a wooden or cane pipe being inserted into one of the legs to act as a blowpipe or tuyere. By these simple means much elaborate work is still done by the native artisans.

To show, in fact, what simple means will in skilful hands produce satisfactory results we will copy from an old cyclopædia * the description of a furnace or forge used by silversmiths and native blacksmiths in the island of Ceylon. For gold and silver, which require less heat than iron, the native artists require a low earthen pot full of chaff and sawdust, in which they make a little charcoal fire; a small bamboo blowpipe, with which they excite the fire; a short earthen tube or nozzle, the extremity of which is placed at the bottom

* Luke Hebert's Cyclopædia.

of the fire, and through which passes the stream of air from the blowpipe; two or three small crucibles made of the fine clay procured from ant-hills; a pair of light tongs, an anvil, two or three small hammers, and a file; and to conclude the list, a few small bars of iron or brass about two inches long, and differently pointed for different kinds of work. The drawings delineate these as commonly made and used (fig. 1).

Fig. 1.—Tools used by native Jewellers of Ceylon.

It is astonishing, says the writer, what an intense little fire, more than sufficiently strong to melt gold and silver, can be kindled in a few minutes. The success of this little forge depends a good deal in the bed of the fire being composed of a combustible material, yet a bad conductor of heat. The blacksmiths of Ceylon require a larger forge, producing greater heat, of which fig. 2 is a sketch.

The two smiths work as here shown, one at the bellows of bullocks' hides, the other at the iron. The bellows are curiously made, and we should suppose them utterly inefficient. The nozzle of each is of bamboo, and so far would be likely enough to answer the purpose re-

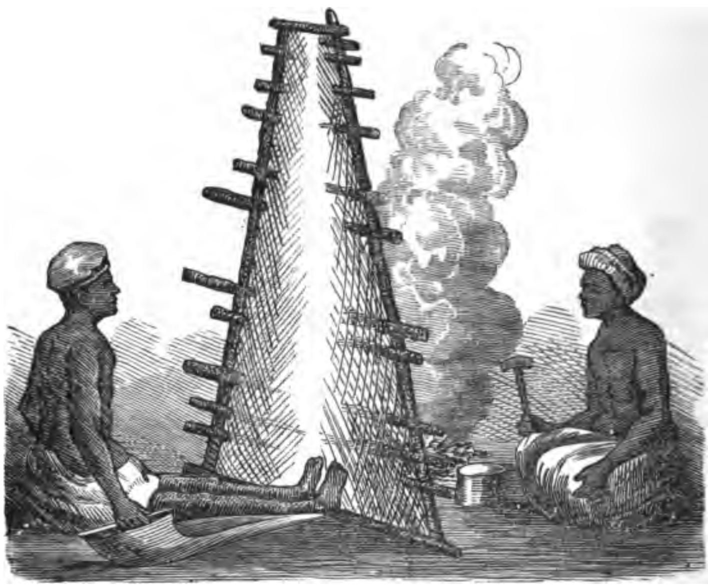

Fig. 2.—Ceylon Blacksmith's Forge.

quired; but instead of such a valve as may be seen in the lower board of a pair of house bellows, which is contrived to allow the wind to enter but not to escape, there is a long slit in each bag, to the edges of which a strip of wood is attached, forming a pair of wooden lips,

which are separated a little way by the hands of the workman as he raises the bag, and are closed again as he presses it down to force out the wind. To an Englishman the tedium, not to say difficulty, of thus keeping up the blast by the action of these rude bellows, one on each side, as he sits on the ground, would be unendurable; yet these natives work away hour after hour, singing at their monotonous task, and turn out work of a very creditable character in spite of these inefficient contrivances, which were probably used in almost the same way by Tubal Cain himself; for, it may be remarked, there is a great reluctance in the native character to take advantage of the superior mode of work introduced to their notice by foreign settlers. The old plan has stood for centuries, and probably will be pursued for many centuries yet to come.

The use of charcoal in these native forges renders the iron of a superior quality, and were it more readily obtainable, we should find it more universally used in England. Coal is nearly always contaminated with sulphur, and this, laying hold of the heated metal, forms with it a brittle compound which boys versed in chemistry are acquainted with under the name of sulphuret or sulphide of iron. When, therefore, very superior metal is required that shall possess such toughness and ductility as will fit it for boiler plates, wire, and similar

purposes, the quality called charcoal iron, in which charcoal has been the fuel used to smelt it, or at any rate to refine it, is always used. It has also been observed that iron produced in those countries where appliances for smelting and working it are of a rude and primitive kind, is always superior to that manufactured where these requisites are accessible. Probably this is due not only to the use of charcoal instead of coal, but to the fact that the native workman requires comparatively small quantities of the metal, and cares little about the time he may have to consume in the various operations. He works, therefore, with the utmost deliberation, and expends on his productions an amount of manual labour which no machinery can rival in quality, though as regards quantity no comparison can exist between the two.

The smelting-furnace used by the Cingalese, as the natives of Ceylon are called, is not very dissimilar to that used by ourselves; it is, however, infinitely smaller, more like a large crucible, and the fire is urged by a pair of primitive bellows worked alternately by the feet. In a small way, indeed, our readers may effect the fusion of iron-ore by way of experiment for themselves, making use of a neat furnace of blacklead like fig. 3.

This may be had of any manufacturer of chemical apparatus for ten or twelve shillings, and will be often found

useful in experimenting upon metals. The hole at the side of the bottom part or stand is for the introduction of the nozzle of a pair of bellows; the blast of air then passes upwards through several holes in the bottom of the middle part or body of the furnace, in which is a little block of plumbago or blacklead, on which the crucible is

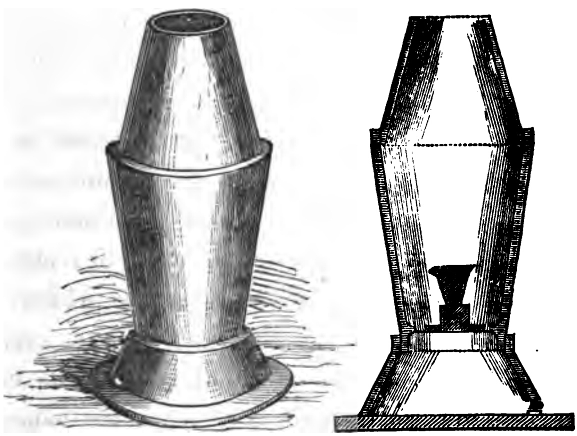

Fig. 8.—Blacklead Furnace (Aikin).

placed. The fuel is charcoal and coke, in small pieces about the size of walnuts, and is packed to about three-quarters the whole depth of the furnace, a few pieces of lighted charcoal being first placed at the bottom; the conical cover is then placed on, and upon the application of the bellows a very intense heat is quickly attained. A little

lime is generally added as a flux, and the metal has to be remelted to refine it.

This process, however, is of course only on a very small scale, and is chiefly introduced to show the trade operation in miniature. It is used in practice merely to test the percentage of iron in any given sample of ironstone, which may, however, be done by the practised hand with the still more miniature appliances of a lamp, blowpipe, and piece of charcoal, a bit of pumice-stone serving as a crucible, or to represent the walls of the furnace. The operation of preparing iron for use, as practised in our own country, consists of first smelting the ore in huge furnaces, which are kept alight for years together; refining the metal which runs from these furnaces by remelting it; transferring this to the puddling-furnace, where it is stirred about at an intense heat until by a natural chemical action it takes the form of tough balls comparable to dough; passing these under a tilt-hammer, and then between huge rollers, by which the fibres are elongated and the mass becomes malleable; and thus forming it into bars or sheets of any desired thickness fit for the several purposes to which it is to be subsequently put by the manufacturers.

A visit to the "Black Country," as the whole region devoted to the iron manufacture is called, especially if the traveller arrives at night, is one that makes upon the

mind an impression not easily effaced. It will certainly put our boys in mind of the infernal regions described by classic poets, in which Vulcan labours at the thunderbolts of Jupiter, and fashions the armour of the immortal gods. The whole country appears to be on fire—hill and dale alike glare with the light of innumerable furnaces, rendering more black and forbidding the smoke and coal-begrimed intervals where no vegetation can grow to vary the scene of desolation. The whole district is like a vast cinder-heap, and the swarthy and sinewy workmen who by day and night preside over the seething furnaces and their adjacent mills might well be descendants of the Cyclopean giants, who were the fabled pioneers of this particular industry. To strangers especially these men show a roughness of demeanour by no means inviting; they dislike interference or interrogation, but are nevertheless by no means the savages they are sometimes represented to be. Their work, it must be remembered, is excessively heavy, and they have but little time to spend in learning the mere refinements of more civilised society. Beneath this rough exterior warm and affectionate natures are by no means rare, and when once these men admit you to their confidence, you will find in them an intelligence, and not seldom an amount of knowledge, you would never have expected to meet with.

To those boys who reside upon such scenes, or who have

special facilities for paying them visits, the present little work will, it is hoped, prove of use by giving them a greater and more intelligent interest in the manufactures there taking place. To those who from various causes are prohibited from personal inspection, our brief notices of "how things are made" ought to prove not less valuable. Machinery and processes which they cannot examine for themselves must needs be brought before them through the medium of such books as the writer now offers to them, and as they peruse its pages we fancy they will be themselves surprised to discover how many articles of daily use have hitherto escaped their close attention, which nevertheless demand in their construction a great amount of ingenuity and manufacturing skill. Even where we may omit the notice of a particular manufactured article, we hope to arouse inquiry respecting its construction, for such inquiry bespeaks an inquisitiveness worthy of all possible encouragement; it shows that our boys are not content to take and to use things as they find them, but to exercise the mind and enlarge the intellect. Both natural and artificial productions—the raw material and the finished article—are sure to be worthy of examination and study; for the works of man, which have resulted from the lawful use of the intellect given to him by God, are more or less a reflex of the still mightier works which that God presents to his view.

All our work is, in fact, first prepared in the great laboratory of nature. There for endless ages have the combined forces of heat and electricity, and "the light of the sun bottled up," as one of our greatest engineers expressed it, been manufacturing, for man's use, both the ironstone and the coal, the copper, the tin, or the precious metals; the fireclay for our furnaces, the fine earth for the use of the potter, the limestone for a flux, the salt for a glaze, and the many other raw materials upon which man is called to exercise his skill. Whenever the exigencies of life have created a want, or the fashions of society a luxury, the needful supply of the material has been found, and suitable means for its economic manufacture; and the greater the demand for any particular article at home or abroad, the more cheaply can it usually be supplied. Productions which are mere waste in one manufacture soon become necessary in another, and that which yesterday was allowed to rot as refuse, to-day becomes a marketable commodity of special and peculiar value. Thus our manufacturing industries are constantly on the increase, and remunerative employment is found for the ever-increasing population, who depend for the very necessaries of life upon this continual springing up of new demands.

As iron, though not considered one of the noble metals, is nevertheless so far the chief that it could be less easily

dispensed with than even silver and gold, we shall enter into more details of its manufacture that we have given in our preliminary sketch, as many of our boys have probably no idea of the many processes required before it can be brought to their notice as some well-recognised article of daily use.

CHAPTER II.

IRON.

THIS substance has been occasionally found as a metal more or less pure, but more generally in the form of ironstone or iron-ore, in which the metal is combined with several substances requiring to be separated from it. A lump of ironstone would appear to a casual beholder like a heavy pebble; and many a boy would think nothing of shying it away at any object that might offer itself as a mark, without a moment's consideration, and certainly without any suspicion of its real value.

The reader must not suppose that this iron-ore is always alike, or that there is but one quality; and it may seem at first strange that the greater part of that which is worked in England is comparatively poor in the quantity of metal which it contains. This is the argillaceous (clayey) ironstone, in which the metal is mixed with

clay, lime, magnesia, and sometimes with bitumen, when it bears the name of "black-band," and is of better quality. This is a carbonate of iron, carbon being chemically associated with it.

The reason that this kind of ironstone is so largely used is that it occurs in vast quantities in the Coal Measures of England, Providence having placed side by side the ore and the material required for smelting it. The richest in metal is the ore called magnetite—the magnetic oxide of iron—next to which is red hæmatite, and then brown hæmatite. These occur chiefly in Sweden, but also in great quantities in different parts of England. Here again, as notably in the Forest of Dean, Gloucestershire, the coal (and timber for charcoal) is close at hand, which has of course in a great degree determined the chief localities of the iron manufacture. Unless the ore is particularly pure, it is first of all roasted, either by laying it in heaps with the necessary fuel in the open air, or in special furnaces. By this some of the grosser impurities are got rid of, and the moisture is driven off, by which means the ironstone is prepared for the operation of smelting. This is done in a special furnace of large size, of which groups are seen like flaming watch-towers in all parts of the Black Country. Such a furnace is sketched in fig. 4.

It consists of a conical brick tower (or stone, if more readily accessible) very strongly put together, and fre-

quently strengthened with iron bonds or hoops, because the weight of the ore, lime, and fuel is very great, and if a furnace should give way, it would probably involve the loss of life, besides an enormous sum of money.

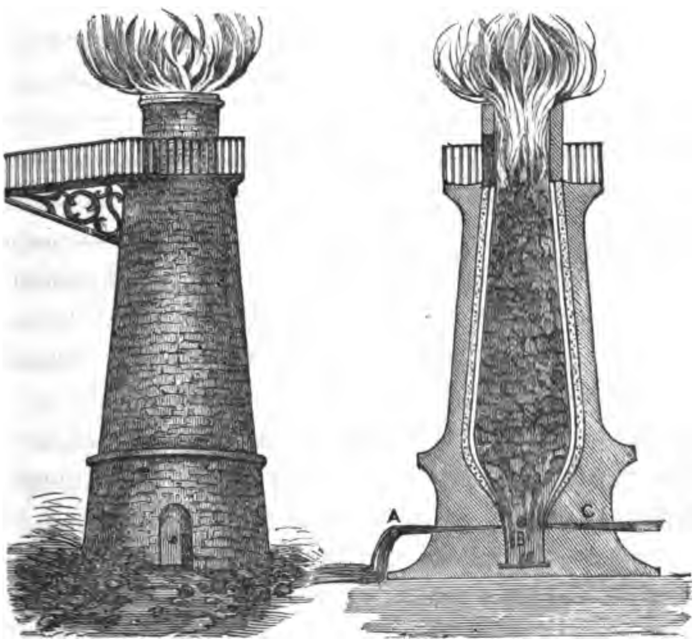

Fig. 4.—Iron Smelting-Furnace.

The furnace is generally built on the side of a hill, for the convenience of arranging from the latter a tramway by which to bring up the ironstone in trucks constructed for the purpose. Sometimes, however, it rises from a level,

and each of the trucks is raised by a "lift" to a platform above, on a level with the top of the furnace; for the ore is thrown in at the top, with the fuel and limestone, and gradually sinks down from the cooler to the hotter part, arrived at which the metal flows off in a stream when the furnace is "tapped," once in about every twelve hours. The furnace is not wholly of stone or ordinary brick, the latter forming only its exterior. These materials would be wholly insufficient to withstand the intense heat. Inside the outer case, therefore, is first a lining of sand, then an inner one of firebrick, the latter being made of a peculiarly infusible clay found in Staffordshire, Leeds, Glasgow, and in nearly all those places producing coal—another instance of the way in which Providence has grouped those substances which our manufactures require to be used together. In the section given here of a smelting-furnace these different linings are distinctly indicated. The inner turret or chimney, with a door in the side for the introduction of the several materials, is merely added as a protection to the workmen from the flaming gases which emerge from the summit, the balustrade also serving to prevent accidents. Very many contrivances have, however, been devised for preventing the necessity of ascending the tower or furnace, as, for instance, iron trucks made to ascend an inclined plane by being attached to an endless chain, and so

arranged as to tip and discharge their contents when arrived at the top of the furnace. It may, in fact, be easily perceived that a good deal of this work can be thus done by mechanical agency alone; but at the same time the operation has to be watched, and the results carefully noted, different qualities of iron requiring different amounts of lime, and, in other respects, somewhat different treatment.

It is to be hoped that our scientific boys are already inclined to ask, "Can nothing be done to prevent the enormous waste of heat which escapes at the summit of blast-furnaces?" We say "we hope this," because it is by using their wits as boys they are likely to develop into clever men—and God gave us eyes and natural senses that we might duly use them to benefit our fellow-creatures.

Such waste, we may at once tell them, is preventable, although there are still many iron-smelters who refuse to economise in this way. We have not yet called attention to the fact that these are not *air*-furnaces but *blast*-furnaces, as they are technically named, *i.e.*, a blast of air is continually urged upon the fuel and the metal to assist in the smelting, similar in kind, but of course immeasurably greater in degree than that produced by the bellows of a blacksmith's forge. Now it occurred to one of our iron-smelters that if a blast of hot air could be substituted for the usual cold blast, a vast saving in fuel

would result, and experiment confirmed that opinion. It was then determined to use the waste heat, which had hitherto been a source of loss, to effect this heating of the air. The summit, therefore, of the furnace was shut in by a kind of funnel, the lower part of which could be closed at pleasure by a conical valve or shutter of iron, suspended to a chain passing over pulleys at the top of the furnace, and thence to the workmen below.

An iron pipe or flue was then inserted in the side, to carry the waste gases to the oven. In this is placed a coil of the pipe which passes from the blowing-machine, or blast-cylinder, to the mouth of the furnace, where it is divided into three parts, each with its separate nozzle or tuyere, directed through proper openings towards the centre of the furnace (A, B, C, of section). The air is thus heated as it passes through the windings of the coil to a temperature of about 600 degrees. Of course this prevents the fuel and iron from being in the least degree cooled by the impact of the stream of air. When a fresh charge is required for the furnace, the stopper or conical plate is lowered from under the funnel, and the coal and ironstone is tipped into the latter, after which the stopper is drawn up, and the operation continues as before. As we do not intend to linger very much about the preparation of the iron from its ores, our object being rather to show how articles are subsequently made, there are many

details of iron-smelting purposely omitted. It may, however, be here stated that coal is not now generally used in its raw or natural state, but is first reduced in proper ovens to the condition of coke, the gases and bituminous ingredients, and also the water contained in it, being thus driven off, as well as the sulphur, the deleterious nature of which we have already pointed out.

Before dismissing this part of the subject, however, it is necessary to explain the object of using lime as a flux, for which purpose a little chemistry must be entered into. Limestone, as commonly found in nature, is one of the earthy carbonates. It is a chemical combination of pure lime and carbonic acid. As such we have it in various forms of chalk, marble, limestone, oyster and other shells. When either of these substances are submitted to the heat of a kiln or of a furnace properly constructed, the gas called carbonic acid is driven off, leaving the lime in its pure or caustic state. When this occurs in the iron-furnace, the lime combines with the earthy impurities in the ore, and fuses into a glassy substance called cinder, or slag; while the carbonic acid as it escapes lays hold of the iron, which is always found to be combined with carbon, as it issues from the blast-furnace. The coke is itself, moreover, carbon nearly pure, and probably supplies this substance in part to the molten metal. Much carbonic acid gas, however, escapes from

the top of the furnace, as happens in the case of an ordinary fire.

The blast by which the fire is urged in a furnace is produced by a blowing-cylinder, in which is a piston like that of an engine, which is driven from end to end in alternate strokes, compelling the air to pass through valves to the furnace. As there is an inlet and outlet valve at each end of this cylinder, the blast thus produced is continuous. The pipe carrying it onward first enters the oven before mentioned, where it is made into a coil for heating, and thence it passes to three tuyeres or nozzles pointing to the fire, one of which is seen at A, another at B, and a third at C, in the sectional drawing of the iron-furnace. The fourth opening, from which, when the furnace is tapped, the iron runs in a stream into moulds of sand, is stopped by a plug of clay, which is broken with an iron bar when the metal is melted. A little above the tap-hole is the cinder-notch, from which runs the slag or cinder in a molten state. This being lighter than the iron, swims upon its surface, and is continually flowing off down an inclined plane arranged for the purpose. This slag frequently contains a good deal of metal, which for a long time was allowed to run to waste, but is now remelted with special fluxes, and deprived of the iron contained in it. It is used for road-making, coping for walls, rockwork for gardens, and is thus in

many ways made useful. Nevertheless, it is produced in such quantities that the hills in an iron district which rise on all sides are in reality huge cinder-heaps, on which, in course of years, an earthy stratum becomes deposited, and here and there patches of stunted vegetation with difficulty grow. An iron district is a terribly dreary and dirty region.

I wonder how many of my readers have seen an iron sow, and her litter of iron pigs? One would deem such a strange compound of the animal and mineral world, yet these are the produce of every iron furnace or cupola in the kingdom. When the iron is melted, as above described, the furnace is tapped by destroying the plug of sand, which the heat has hardened; and the metal is then conducted into a sand bed, in which, by means of wooden blocks of a suitable size, a number of little oblong recesses or pits are made. The main ones are longer and larger than the rest, which branch off right and left. The iron runs, therefore, first into these larger moulds, and thence into the rest. The result is a number of masses of crude metal called *sows* and *pigs*, which thence pass through various processes, to deprive them of their brittleness and render them pure and malleable (*malleus*, a hammer). For when these sows are cold they are so brittle that by being dropped on a block of wrought iron they will break short off like glass, and

the broken ends appear of a beautiful crystalline form, bright and shining, and of various tints, according to quality. A sample is thus always broken, on purpose to test the character of the metal, which a practised hand will value at a glance. Even the same ironstone will produce various qualities of metal, depending on the fuel-flux and state of the furnace.

It will probably surprise some of our young readers to learn that iron in this crystalline condition may be re-melted without difficulty; but if they were to try and melt a piece of wrought metal, such as they could pick up at a blacksmith's, they would find that instead of melting it would burn, throwing off a number of bright sparks, as it does when brought to a welding heat at the forge. A piece of wrought iron, moreover, is only broken with difficulty, by being bent backwards and forwards until it gives way; and when it is thus fractured, it appears to be composed of a number of long fibres instead of crystals, so that its character since it was numbered among the pigs has evidently been much refined and improved; its education has been evidently well carried out, and we shall find satisfaction in investigating the principles on which it has been conducted.

The pig-iron is not pure metal, but, even when it has been carefully smelted with good coke, contains many impurities, as silicon, carbon, phosphorus, sulphur, and

probably manganese. These have to be got rid of as far as possible, if the iron is to be used for any other purpose than rough casting.

To effect such riddance it is first of all refined, then puddled (sows and puddles are, we fancy, generally no strangers to each other). The first operation is conducted in a furnace of peculiar shape, called a finery, which need not be here described in detail, as the main object is to show in this place what it is designed to effect, and in what manner its work is done. Its object is to supply to the iron a charge of oxygen, which gas has the property of combining with certain substances (*all* substances probably, with very few exceptions), and by such combination forming new compounds. The blowpipes, or tuyeres of the refinery are six in number, and are so arranged as to pour upon the molten iron a continual and forcible stream of air, by which it is kept in a state of movement or ebullition. The best coke is used as fuel, and the air is not now heated as it passes from the blower to the furnace.

The air of the blast, containing as it does a large amount of the required oxygen, and impinging violently on the boiling and seething metal, combines with its carbon, and carries it off in the form of carbonic oxide or carbonic acid gas, which escapes from the chimney. Carbonic oxide burns with a blue flame, and is probably partly consumed.

The sulphur also combines with oxygen and escapes, and the silicon and part of the oxidised iron form a cinder or slag on the surface of the metal. The latter is therefore deprived of many of its impurities, and runs from the finery considerably altered in character and appearance, being silvery, and not so grey in colour. It now bears the name of "fine metal." I think we might not inaptly call it *Roast Pig.* During the process just described water is continually thrown upon the molten iron, both to assist it in separating its cinder or slag, and also to render it brittle, because it now has to be broken up with sledge-hammers, thence to be handed over to the not very tender mercies of the puddler. The action of the water and the hammer, therefore, may be said to produce on our pig something akin to "crackling."

The next operation is carried on in a furnace very like an ordinary baker's oven—*i.e.*, it has an arched top and flat floor. In this, for the first time, the iron is not intermixed with the fuel, the coal or coke—generally coal—being laid on a grate at one end of the oven, which is separated by a low wall, called a bridle, from the central part or hearth, on which the bars of iron are piled, and also by a similar bridle from the third division just under the chimney. The arched roof reflects or reverberates the heat upon the iron. I need hardly remind our boys that *re-verbero* signifies to beat again, or perhaps to hit back

in return for a blow given, the flame being beaten back upon the iron before it is allowed to pass on to the chimney. The heat produced is very great, and in about an hour the iron is melted, and fit for the peculiar work of the puddler. He uses two long bars of iron, one somewhat hoe-shaped, the other flattened only, but straight, each about eight feet long. These he introduces through a hole in the door of the furnace, and with them stirs up and works the melting mass with great labour and no little skill. Some slag and "mill scale," similar to what falls from the heated and hammered iron in a smith's shop, and which is called in chemical parlance "black oxide of iron," is always added to the metal in the puddling-furnace, as this gives up its oxygen to the iron, which is the object in view. Looking into the furnace at a particular point in the operation, you would see nothing but a glowing mass, on which you could scarcely keep the eye a moment. The workman, however, sees the iron bubbling and boiling wondrously as it imbibes the oxygen, and he turns on all the heat available by opening the damper in the chimney to its full width, and by dint of the skilful use of his iron "rabble," and its companion "paddle," he gets the now pasty mass into lumps or blooms of about eighty pounds weight, which are then withdrawn for further operations. During the process the slag flows off, and the iron becomes pure. I do not

think any exact explanation has been given of the nature of the above process. It results in a further partial oxidation of the iron; but why this should render it pasty and capable of being thus worked, and who discovered the art of puddling, I cannot say. In England the process seems to date about 1780, and Cort of Gloucestershire, an ironmaster, was the one who did most to bring the art to perfection. He, as is frequently the case with inventors, did not reap the fruits of his skill, but died a poor man; though others, to say nothing of his country, were so highly benefited by his discoveries, that many huge fortunes resulted, and England stepped at once into her proper place as the greatest seat of the iron trade in the world.

We may now consider the iron thoroughly deprived of its carbon, as well as of all other impurities, although some will not entirely separate from it by any of the above processes. Phosphorus, for instance, is found in nearly every sample, and probably the iron is none the worse for its presence.

CHAPTER III.

TILTING AND ROLLING.

WE now pass from the preliminary operations of the iron manufacture, which have supplied us with a lump of pure metal in a condition which it has not hitherto attained. Deprived of its carbon in the puddling-furnace, it will now bear to be hammered and rolled, and otherwise tormented, without fracture. It has become tough and malleable. As soon as it leaves the hands of the puddler, it is taken in its highly-heated state, on a little iron truck, either to the squeezer, tilt-hammer, helve, or steam-hammer, by which the metal is pressed or hammered with enormous power until it becomes a thoroughly compact mass, and whatever cinder may have got into it in the puddling-furnace is removed. There are various forms of both these machines. The old tilt-hammer was worked by water-power, and was of no very large size; the helves, similarly driven, were more massive. The squeezers are of compara-

tively modern date, and are not always so favourably received as the hammer. Probably either effects the desired object equally well, but there is a prejudice in favour of the older friend, which we may adopt as a moral.

"New friends may be wittier, handsomer, bolder,
But until you've proved them, stick to the older;
A new coat may fit, and look faultlessly nice,
But the wearer feels much as if gripped in a vice;
We gain little comfort from being well dressed,
So I say that old coats and old friends are the best."

The process, in whichever way it is conducted, is called shingling, and a noisy process it is, though not nearly so bad as a boilermaker's. The tilt-hammers have been mostly discarded in the manufacture of iron, because they were found too light for the more massive productions of modern days, and the helve and steam-hammer are now generally employed. The helve (fig. 5) is a ponderous hammer, lifted by revolving cams on the axis of the driving-wheel. Steam is the power used, except where water is plentiful. The whole helve is now of iron, but used to be of ash, and was made up as a compound beam bound with iron hoops. An old-fashioned forge on the banks of a river, amid beautiful scenery, was a picturesque object in days gone by; but everything has changed now, and the ogre steam has swallowed up its weaker rivals, driving the manufacturer and his machines

from the old haunts to the wild and black country of coal-pits and cinder-heaps, so that it is only here and there (as at Tintern) that one sees such manufactures still carried on near the homes of salmon and trout and grayling, whose ears, if they have any, seem insensible to the sounds of noisy industry in their midst. The actual hammer-head, which is rapidly worn out by the heavy work it has to perform, is not made a permanent part of

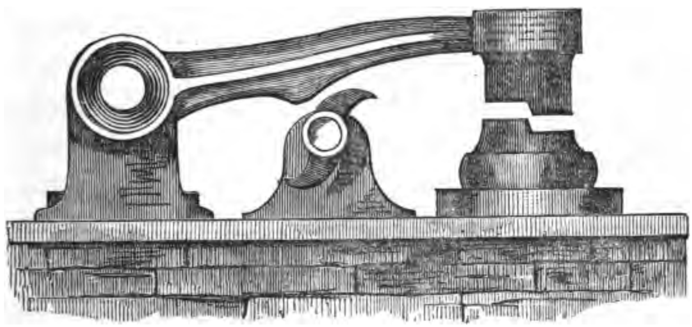

Fig. 5.—Helve.

the machine, but fits into a socket in the extremity of the helve, so that it can be speedily removed and replaced by a new one, spare heads being always kept ready, so as not to delay the work, which is carried on night and day. The face of the hammer, and that of the anvil, is divided into three parts or steps, as it is found better in practice to subject the puddled mass to a force which shall affect it variously, spreading it out sideways, or lengthening or flattening it at pleasure. The weight of such a

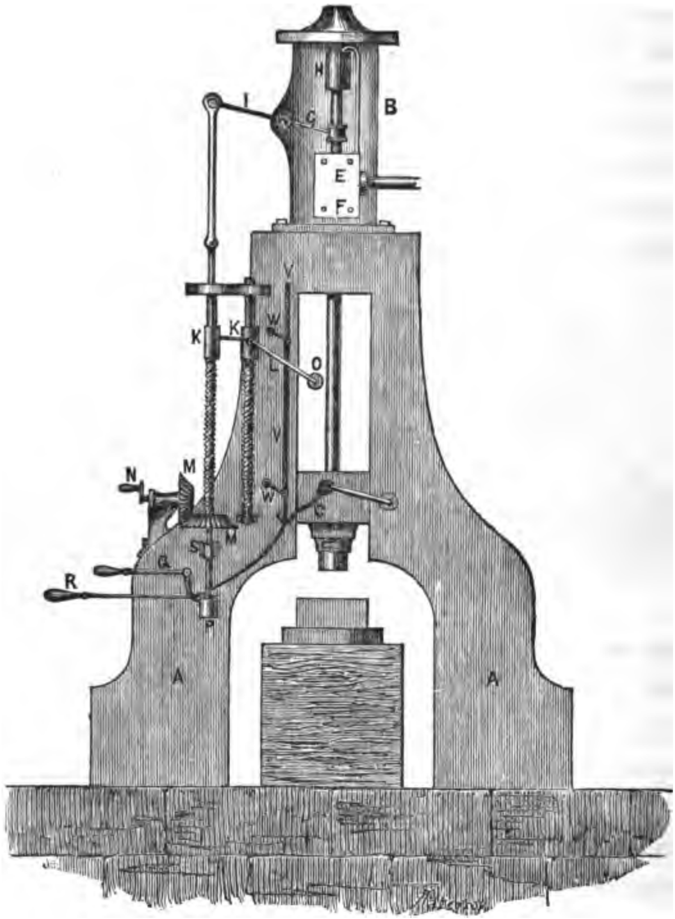

Fig. 6.—Steam-Hammer.

hammer is 6 or 7 tons, and it makes about sixty strokes a minute; so that the reader can readily understand why the head of a helve and its anvil require very frequent renewal.

Fearful as the blow of the helve may be, it is a mere joke to that of the steam-hammer (fig. 6), which nevertheless is so beautifully arranged, that it will crack a nut without injuring the kernel, a feat it is often made to perform for the delectation and astonishment of the visitor. In many ironworks the helve has wholly been superseded by this machine, which is very simple in principle, though it may appear somewhat complicated in detail. There is first of all a massive frame of wrought or cast iron, A, fixed to a solid base of masonry below the floor of the workshop; for the vibration caused by the descent of the hammer is enormous, and, in spite of all precautions, jars and shakes the whole workshop and all within reach of its effects. At the upper end of this frame is a steam-cylinder B, in which is a piston like that of an engine, but the piston-rod is below, and at its extremity is the hammer-head C. Steam is admitted below the piston, and the hammer is thus raised, and when at the desired height, communication with the steam is cut off, and air admitted freely, and down falls the hammer by its own weight upon the mass of white-hot metal upon the block below called the anvil. The blows, mighty as they are, are given

at the rate of about one a second. So far the machine is easy of comprehension, but practically there are certain requirements to be fulfilled to render it efficient for the purpose designed. In the first place, the mass of iron to be hammered will not always be of equal size or thickness; sometimes, therefore, a light blow will be required, and sometimes a heavy one. Then, again, the workman must have time between the strokes to adjust the mass of metal, and consequently he must be able either to arrest the strokes at pleasure, or to let them go on at high speed; so it becomes requisite to admit or cut off the steam in a moment, to cause the hammer to rise to its full height so as to fall with its utmost force, or to allow it only to rise a few inches. By the very clever arrangements now to be described all these several conditions are fulfilled, and the whole is brought as much under the control of the workman as the light hand-hammer by which the reader may drive a tintack or a nail. In fact, the steam-hammer is quite as competent to drive a tack as to reduce a huge mass of iron to a flat plate. Now all these various requirements are met by simple mechanical arrangements, which are self-acting and under easy control, so that a single attendant can, by moving a couple of levers, cause the hammer to rise and fall, stopping each time in mid-air, and then, the moment the iron is in position, come thundering down upon it with a force of some tons.

This is accomplished by the slide-valve E and its fittings. This valve is contained in the box F at the bottom of the cylinder, and its valve-rod is seen at G. A slide-valve, we may explain to those few who have never seen one, is a plate or shallow box, which, by being moved up or down, opens a hole or slit under it, and admits steam or air, as the case may be. Ordinarily this valve is open in the steam-hammer, so as to admit steam under the piston in the cylinder, and thus keep the hammer raised. To this end the sliding-plate is *below* the steam-port. It is so kept partly by its own weight, and partly by the following contrivance:—H is also a small cylinder with a piston (like that of a syringe or squirt) inside it. This is attached to the rod of the slide-valve. Steam is admitted to the upper side of this piston, pressing it down, and so keeping open the valve already described. In order to shut off steam, therefore, in the big cylinder, and so allow the hammer to fall, we must draw the slide-valve rod upwards, and so raise the slide and prevent steam from entering. This raising of the valve-rod is of course resisted by the pressure of the steam in the small cylinder H, which acts therefore as a spring. One end of a lever I is attached by a pinned joint to the valve-rod, and at the other to a vertical rod by a swivel joint, for reasons that will be presently understood. This rod is screwed for a portion of its length, and another precisely similar

D

screw is fixed so as to be free to revolve parallel to it. The first screw, however, is cut with a right-handed thread, the second with a left-handed one. This is necessary, because they are geared to each other, and therefore turn in opposite directions, but the nuts which slide upon them are needed to move in the same direction, up or down, and to move precisely together. These nuts are marked KK. That on the right-hand screw carries the stud on which is hinged the bent lever L; that on the left carries a pin which acts on the tail of this lever. The whole of this screw must be free to move up and down, and it passes, therefore, through two sockets. This movement, however, would interfere with the acting of the bevel-wheels MM, which work by the handle N, and cause the rotation of the screws on their axes. The wheel, therefore, on the screw is merely slipped over, and is kept from turning round by a pin or feather and slot, as shown in fig. 7. We illustrate it because it is a common arrangement in machines, especially in drilling-machines, and is a simple but very important mechanical contrivance. It will now be plain, we think, to the reader, that, by turning the winch-

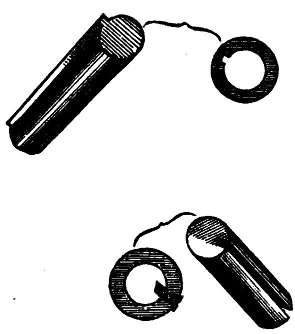

Fig. 7.—Slot and Feather.

handle, both these ferrules will move up or down, carrying with them the bent lever, and bringing its end O nearer to, or more distant from, the head of the hammer. It will also be clear that if the hammer, or a stud upon it, touches the end O of the lever in its ascent, it will cause its other end to descend, and, by its connection with the left-hand screw, will cause its descent also, but without such descent affecting the relative positions of the bevel-wheels. It will also be plain that when the screw moves thus *downwards*, it will, through the means of the upper bent lever, pull *up* the rod of the slide-valve against the resistance of the steam in the small cylinder; and this will cut off the steam, and allow the piston to descend, *if the air is also admitted above it*, for without this the piston would remain suspended, or descend but a very little way. Moreover, the piston could not ascend with the admission of steam below it, if the air were shut in between it and the top of the cylinder. To admit this air there are a number of holes round the upper part of the main cylinder of the machine, which remain open except when the piston itself closes them by being opposite to them in its ascent. When this happens, the air shut in above forms an elastic cushion, which takes off a great deal of the jar that would otherwise ensue, because it gives a little impulse to the piston as it reaches its highest point,

starting it on its downward course. This is technically called "cushioning."

The steam is admitted from the boiler into the steam-chest, and the small pipe from this admits steam to the small cylinder freely, this being always open. Now we may suppose the port in the slide-valve open, and that it will remain so while pressed down by the steam in the small cylinder acting on its rod by means of the piston at the upper end. The result will be that the large piston in the main cylinder will be raised, and will lift the hammer at the end of the piston-rod. The latter, thus raised, cannot drop till the steam is cut off by raising the slide-valve. This is accordingly done, for as the hammer passes the end O of the bent lever (which has a roller at the point where the projecting head of the hammer will touch it, to lessen the shock) it will *raise* this, and thus, by *lowering* the other end, pull down the rod with the screw, and, lifting the valve-rod, shut off the steam. The exact time at which the hammer-head will strike the end of the bent lever will depend on the position of the latter, and this, as explained, is regulated by raising or lowering the nuts of the screws by means of the handle attached to the bevel-wheels. But under these conditions the hammer will begin to fall, and then the steam will raise it again; because, as soon as the lever O is passed, the valve will again drop, and admit steam to the cylinder as before.

The hammer would thus oscillate, or move up and down a certain distance, but would not reach the metal on the anvil below. For the latter purpose it will evidently be necessary, after the left-hand screw has been depressed (closing the steam-valve of the large cylinder), to retain it in this position until the hammer shall have made its full blow, and then release it instantly, and allow steam to enter and raise the hammer as before. This is effected by an automatic or self-acting contrivance, as follows:—

The rod on which the left-hand screw is cut, and which, as explained, can be raised and lowered without moving the wheel through which it passes, is enlarged at P by a boss, and at Q is a kind of trigger or catch, with a handle attached to it, the weight of which tends to keep the short end against the enlarged part of the rod of the screw. When the latter, therefore, has descended a certain distance, the trigger slips over the boss and falls against the smaller part of the rod, preventing the boss from moving upwards, and this, therefore, holds the rod also off the slide-valve, keeping it closed, and shutting off steam. Under these conditions the hammer will fall upon the work laid on the anvil below. And now comes into action a very ingenious application of a mechanical law elsewhere explained in this book—viz., the law of *vis inertiæ*, by which every moving body tends to continue its motion in the same direction until some external force, impeding its further

progress, brings it to a state of rest. Pivoted to the hammer-head at C is a bent lever weighted at one end, the other end, which is shorter, resting against a vertical bar VV, attached to the framing by links WW like those of a parallel ruler. When the hammer falls upon the iron, and is suddenly checked in its descent, the weighted end of the lever, not being similarly prevented from further descent, drops by the concussion, the spring by which it is otherwise sustained yielding to its impetus. The opposite short end, therefore, of the lever kicks against the vertical bar VV, which is thereby caused to move sideways, and its curved end striking against the trigger Q, knocks it away from the boss of the screwed rod, which at once rises under the action of the small piston, and, opening the valve, readmits the steam to raise the hammer. The attendant can by means of the lower handle draw down the screw at pleasure, and close the valve, or by the other he can move back the trigger from the boss. He can therefore keep the hammer oscillating up and down until the iron is placed in a proper position to receive the blow.

The steam-hammer is, on the whole, one of the most ingenious adaptations of certain mechanical powers, in the whole range of machinery used in the arts and manufactures. It places a force of almost irresistible power within the management of a child. It will drive a tin-

tack with gentle taps into a piece of deal, or it will reduce by a few mighty blows a seething mass of iron from the form of a large cubical block to that of a flat plate, and withal so speedily that it can be thence removed to the rolls, and further reduced to the condition of a thin sheet before it has had time to grow cold. I wonder if the Cyclopean forgers of Jupiter's thunderbolts in their subterranean workshops would have combined to get up a "strike" if old Vulcan had ventured to introduce such a tool to replace the hand hammers and sledges wielded by those brawny arms. Of course my classical readers have no doubts as to the fact of the existence of those giant blacksmiths.

Premising that Sheffield is meant by the word *Sephilœa,* we might give the following lines from a Latin poem of Dr. Dering, a Dean of Ripon, as an exercise for our young readers. The *longè resonat,* however, is not so applicable to the steam-hammer as might be supposed, because its heavy *thump* is heard at no great distance, while the clang of the boilermaker's hammer sounds far and wide, and is deafening when close at hand.

"Mille ardet Sephilœa focis. Fornace liquescit
Montibus effossi vicinis massa metalli,
Et longè resonat glomeratis ictibus incus,
Nec lunæ aut cotis cessat labor. Insuper arma
Ante oculos fabri ponunt Romana; notantque
Mutandum siquid; seu sint exempla sequenda."

In the workshops, however, alluded to in the above quotation, it was not exactly boiler-plate, but *armour*-plate, which had to be fashioned by the workman's ceaseless hammer, and in the fashioning of which these hardy smiths were endeavouring to take a hint from their enemies. There were no rolling-mills then, and the iron sheets were made and formed by the laborious process indicated above.

To move a large mass of iron about under the steam-hammer or the helve, a long iron bar is raised to a welding heat at one end, and laid upon it; the first blow attaches it to the white-hot metal, and the workman is thus enabled to move the latter about. The end of the bar, however, is generally made with a cross handle, to give him more power, and he is further assisted by his companion or mate, who is similarly provided, or who uses a gigantic pair of tongs, and other similar means of manipulating the mass. A bloom, however, from the puddling-furnace rarely exceeds eighty or ninety pounds, and can be turned about by one man. In large *forgings* the case is different, and two or more men are needed.

The puddled mass we may now suppose to have been freed from any cinder by the squeezer or hammer, and to be considerably flattened, if intended for further reduction, to the form of a plate or sheet, but if intended for

bar-iron for rails or other purposes, the shape will receive the necessary modification under the hammer, being elongated in one direction only.

In either case the metal is probably destined for the *rolls* (figs. 8 and 9). These are cylinders of iron, turned very truly in a lathe, and either perfectly cylindrical from end to end, for rolling plates for boilers, bridges, tubes, or other of the many purposes to which flat plates are now put; or variously grooved, with semicircular, angular, or parallel grooves, so that when a bar of hot iron is made to pass between them, it becomes of a sectional form corresponding with these. A semicircular groove in each, the grooves being opposite to each other, will result in a round bar, triangular ones in a prismatic or square bar. For railways, in which the rails vary in form, and are either rectangular, hammer-headed, or doubly hammer-headed, each roller will need a groove corresponding to the half section. Of whatever form the rolls are made as regards their surfaces, there is an arrangement for adjusting them at the required distances from each other. This is effected by a screw, with arms bent so as to be within reach of the workmen, and at each end; so that as the plate gets thinner the rolls can be brought nearer and nearer, until the plate is of the thickness required.

To prevent the rolls from heating, a stream of water

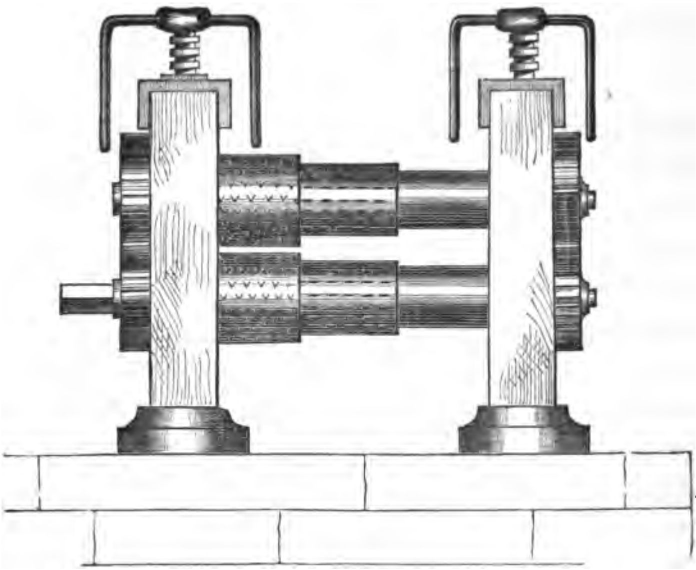

Fig. 8.—Rolls for Bar-Iron of various sections.

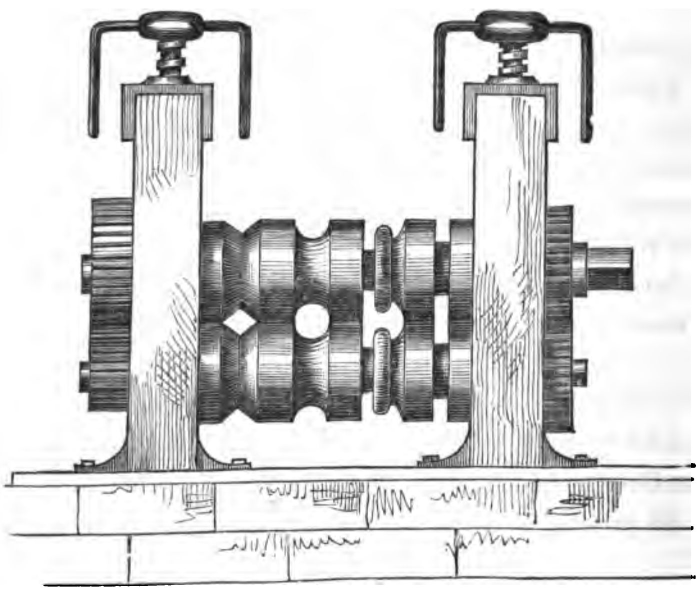

Fig. 9.—Rolls for Bar-Iron of various sections.

trickles constantly over them from end to end; and as, in spite of all care, they necessarily wear more or less unevenly, they require to be freshly turned from time to time. This is usually done in a lathe kept on the premises for that special purpose. The speed at which the rolls are driven is very great, so that the plate, when first inserted, goes through in a moment with a sharp crack. The second workman receives and tosses it back to his fellow, or it is sent back through another pair of rolls turning in the opposite direction. A few minutes reduce a thick lump of metal to a broad and long plate, the whole operation being completed "at one heat," or before the iron has had time to get cold.

In the figures are two sets of rolls, and it will be seen by the white spaces the shapes of the plates or bars that will thus be formed. The very rough part of the first set is used for the preliminary work on a bloom, by which cinder is pressed out, and the piece reduced to a rough sheet, or rather plate, the surface of which will be full of indentations. It is then passed between the plain rolls.

In the above operation the crystals or granules of the metal become fibres, from being each drawn out in one direction, so that the iron after being rolled is no longer brittle; but sometimes a bloom from the puddling-furnace will fly to pieces from having been insufficiently decar-

bonised. In such cases the puddler has usually to submit to a fine, and generally gets considerably *chaffed* as well, for his negligence.

We may as well follow up now one of these iron sheets in its plain state, and see what may be done with it. First, it may be, and very often is, passed between "slitting rolls," which cut it into strips of any desired width. These rolls are shown in fig. 10, and it is evident that, during its passage between these, a sheet will be divided lengthwise into as many strips as there are divisions in the rolls, the thickness being that of the original plate. Rods of flat and round iron are both equally the result of rolling; and the reader can understand how easy it is in this way to make these rods of any required sectional shape, as grooves can be turned in one or both at pleasure.

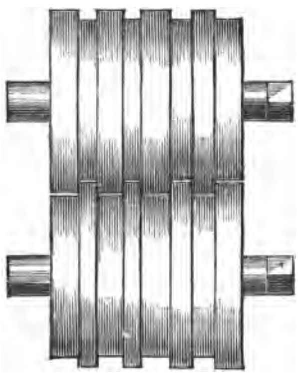

Fig. 10.

We have now traced the iron steadily through the processes required to reduce it from its ore to malleable rods fit for nails and other purposes, plates for boilers, girders, tanks, &c., and sheets for lighter articles like coal-scuttles, roofs of buildings, stove-pipes, and other

common and well-known requisites. Let us first inquire how it is further reduced to the condition of wire; and as we may as well in this case leave the Black Country for a more secluded spot of great beauty, we will pay a theoretical visit to the precincts of the Abbey of Tintern, in Monmouthshire, upon the banks of the Wye, and describe the process as carried on there before our eyes.

CHAPTER IV.

WIRE-DRAWING.

HAD we not been already introduced to iron sows and pigs, we should have been able to make acquaintance with them here at Tintern, where they flourish in as great quantities as salmon pink, or the more mysterious elvers. There is but one wire-drawing establishment here, however, picturesquely situated among the towering cliffs and woody banks of the loveliest stream in England. The river, or a tributary stream, is here made to take its share of unromantic toil, and work the blowing-machines by which the furnaces are kept up to the intense heat that is requisite. Even here, however, we believe steam has established its sovereignty, and does the heavier work of converting the iron to the form of wire. But here we meet with what we failed to see in the Black Country already visited. The fuel used is charcoal, which is (or was not long since)

transported on the backs of mules and donkeys from the Forest of Dean, some ten miles distant from the furnaces. This fuel is solely used at Tintern, because only the best qualities of charcoal iron will stand the process of rolling and drawing into wire.

Charcoal-burners of the forest have often been made a subject for the pencil and brush of the artist, for very picturesque they are in their sylvan home. The process of making charcoal is a very simple one, yet needs some experience and care; but, as we shall presently explain, that used at Tintern (and in the district for private houses) is not all made on purpose for fuel, but is the refuse of a chemical process for producing wood-naphtha. The ordinary process of charcoal-burning is conducted as follows:—The wood is cut down and split into billets of a convenient length and size, which are then built up in heaps of a conical form, dry wood and other combustibles being first laid as a means of setting fire to the mass. The whole pile is then overlaid with clay and turf, a hole being left at the summit of each conical heap for escape of smoke; other holes are also left near the lower part to admit air. Thus built, these piles have something the appearance at a distance of a group of Indian wigwams, in which fancy may easily imagine a happy family of Redskins sitting round the fire smoking the pipe of peace while discussing the scarcity of scalps, by the number of

which hanging at the waist the dusky braves were wont to enrapture the eyes of the Indian belles. Well, happily we have no such custom, though the pipe of peace—an honest clay blackened with use—is very generally to be seen in the lips of our dusky charcoal-burners, and not seldom also in the lips of their wives. When the pile of wood is ready, it is ignited at the base, and is soon in a state of fierce incandescence, flames leaping forth from the various orifices. As soon as the fire, however, is thoroughly lighted, all the lower air-holes are stopped with turves, and the whole heap then smoulders quietly until the substance of the wood is charred completely through. The exclusion of air prevents it from being "burnt" or converted into *ashes*, as it would otherwise be, and it retains its outward form and inner substance, still appearing like wood with its radiating marks and pores, but all alike is blackened and converted into carbon, which can be easily reduced to powder if desired.

The other way of making charcoal is to place billets of wood in iron cylinders called retorts, and submit them, thus shut up, to the heat of a furnace. In this case we save much of the substance of the wood which is wasted when charcoal is made in the manner already described. This process can be shown by means of a little simple chemical apparatus which I have here copied from Griffin's "Chemical Recreations." I give it because it will show

the results of burning wood in close vessels better than any other illustration (fig. 11).

The apparatus is merely a bent tube, or tube retort, held over the flame of a lamp (here it is a gas-lamp, but a common spirit-lamp will do as well). This is connected with a bent tube called a receiver, also of glass, by means

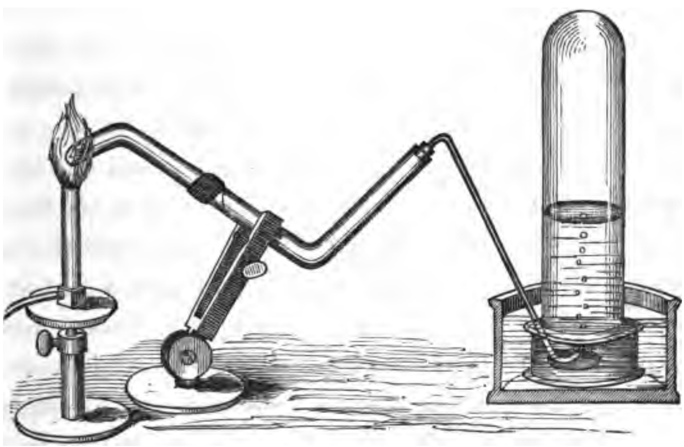

Fig. 11.—Distillation of Wood

of a bit of indiarubber tubing. The end of the receiver is corked, and has a smaller tube passing from it to the pneumatic trough. This is merely a basin half-full of water, in which there is a shelf or stand with a hole at the side and in the top. It is here made as an earthenware box, and may be replaced by a flower-pot with a piece knocked out of one side. Over the hole in the top of this stands a

glass tube, or it might be a phial, or any open bottle of small size, which is filled with water, and then, while the finger is held over its mouth, inverted so that the mouth is under water in the basin. If the finger is then removed, the water will not run out, and it is set up on end on the shelf over the hole, as seen in the drawing. In this way, you see, we shall catch all the products of our cookery or distillation of wood, as it would be called. This wood we place in the retort, and very soon it will become red-hot. First it will emit steam and vapour, because all such substances contain more or less water, and this will condense in the cold receiver, and run down to the bent part. In addition to this, gas will pass over, and rise in bubbles through the water, which it will drive out of the receiver or upright tube, and will occupy its place. Now the charcoal will be at once seen, the wood having become charred, and converted into this substance. At the bend of the tube is what looks like dirty water; but though it is partly water, it contains two substances besides—a thin clear liquor, and a thick brown one. The first is acetic acid (a very strong vinegar) and wood-spirit, or wood-naphtha, mixed together; the brown liquor is wood-tar. But besides these there are always other substances in combination or mixed up with them. Now this little experiment is, in miniature, what are called chemical works, in which, by dry distillation of oak and beech in iron retorts, are pro-

duced large quantities of wood-naphtha, tar, and acetic acid, each of which has its own special uses in our various manufactures. It is a curious fact, moreover, that various substances, allowed perhaps for years to run to waste in the production of some other substance required, have ultimately become of even greater value than the substance originally desired to be made. Such, for instance, is benzoline, once allowed to run to waste in the manufacture of paraffine, and which is now largely used for lamps and other purposes; and glycerine, which was once considered a waste production in the manufacture of stearine candles.

The produce, however, of this wood distillation which we have to deal with now is simply charcoal, the refuse of the manufacture of wood-naphtha. This, when taken from the retorts and cooled, is packed in sacks and conveyed to the ironworks. Probably (for our reminiscences of Tintern date back, we grieve to say, twenty years) the old mode of transportation has become a thing of the past. At that time, indeed, a railway was being arranged in the immediate district, which bid fair to exterminate a good deal of the old romance that for centuries had lent its charm to the vale of Tintern. Probably, therefore, as we have remarked, the mules and donkeys, with their gipsy-like drivers, are no more. But they formed a curious sight to a stranger as they appeared in a long line creeping in and out among the woody

lanes, scarcely ever two abreast, but treading in each other's footsteps, like Indian braves upon the war-path. With this charcoal only the iron used for wire is smelted; because, there being no sulphur, the metal is not deteriorated, but refined and purified. As we have said a good deal about the smelting-furnaces and finery, we may quit these, and go across the yard to the rolls, where the operation of reducing the iron to a coarse wire fit for fencing and similar purposes is carried on. Imagine a large shed, the floor black with scale and dust, furnaces on one side roaring and devouring our litters of pigs, and roasting them with the fury of demons. We ask to look inside one of these mighty ovens. A lever is pulled down, and the sliding-door is raised, and we at first only see flames writhing and twisting, and licking with their sharp tongues all sides of their prison-house. Presently we distinguish some of the wretched pigs almost in a molten state. One of these is seized, when just "done to a turn," and flung across the floor to be further tormented. It is to be passed, in short, between those relentless iron rolls which will turn pig into snake in a twinkling. The rolls are iron cylinders, of which three, one above the other, revolve in contact. But at intervals a groove has been turned in each; so that when in contact, a round, square, or other shaped hole is formed by the two sections, like fig. 12. According to the shape of these

grooves will be that of the bar that is thus produced; but at Tintern round wire only is made in this way. A workman stands at the furnace, and one on either side of each set of rolls. The former, withdrawing a pig from the furnace, tosses it across the floor, where it is seized in

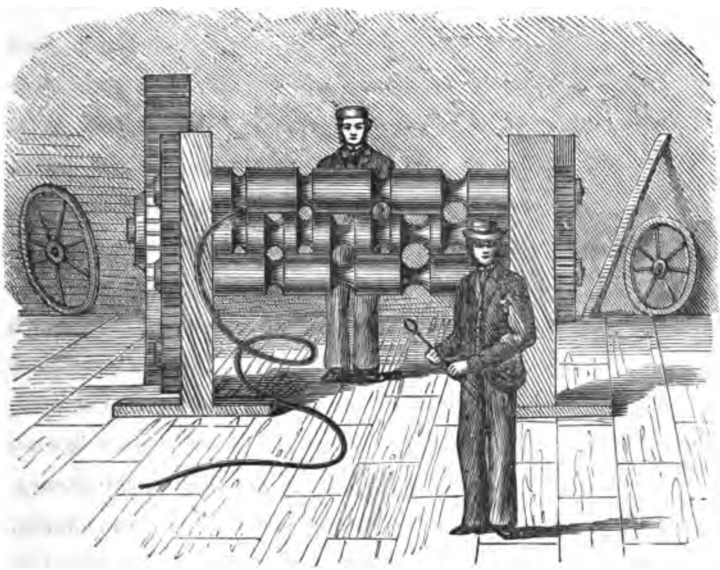

Fig. 12.—Rolls for Wire-drawing.

a large pair of tongs, and one end inserted in the largest groove or hole of the rolls. A sharp crack announces that our pig's first terrific squeeze is over; and instantly another crack is heard, and the iron comes back on one side elongated and rounded. There must be no rest, however,

as the iron must be worked while at a great heat, and thus a few more cracks and groans succeed as the bar is passed to and fro through smaller and smaller grooves, and in a few minutes the once plump pig is seen wriggling forth from its last journey a long, straggling, red-hot serpent, out of the way of which we find it prudent to hasten. This is laid hold of by another workman, and coiled upon an iron reel, from which, after the ends have been secured by a turn or two of binding-wire, it is taken and added to a heap of similar coils which await the further processes of annealing, pickling, and drawing. The rapidity with which the above operation is effected can hardly fail to strike the observer; and when one compares the agricultural labourer, slowly following his plough up one furrow and down another, with these mechanical workmen, who cannot rest a moment lest the metal cool, one can see how it is that the minds of the latter are so much the more active, and that, in all their movements, and even in speech, they stand apart from the others, almost like a different class of men. Moreover, it generally happens that mechanical craftsmen repair to their reading or class room after the work of the day is finished, while the agricultural labourer is too frequently contented to spend *his* evening in the public-house, in a very dreamy and lethargic way, as if he possessed a mind incapable of enjoying intellectual pursuits.

Yet here again, as education slowly advances, improvement will, almost as a matter of necessity, take place, and again, boys, I appeal to you to promote the good work which will take place in your manhood. Agricultural labourers have not at present, perhaps, an equal chance with their mechanical brothers; there is more facility in the large towns for obtaining books and papers, and for the establishment of literary and mutual improvement societies. But notwithstanding all drawbacks, a great deal more might be done in this direction in country villages than has yet been accomplished; and if the better educated and more influential will but set their shoulders to the wheel, and try to provide their poorer brothers with means of mental improvement and intellectual recreation, there can be no doubt that grand results will at length ensue. Whenever you see an evil, boys, either now or in later life, don't be content to deplore it, but go courageously to work, and endeavour to remove it.

But while I am talking of refining and polishing our labourers, I ought to be telling you how the same work is accomplished in respect of the wire. After leaving the rolls and becoming cool, the iron is found to have become very hard and stiff; and indeed it has had enough to make it so. It must now be rendered soft and ductile, which is accomplished in the following manner. The coils of wire

are packed in what may be called iron tubs, and are then placed in furnaces constructed for the purpose, where they are subjected to a low red heat. They are then withdrawn from the furnaces, and allowed to cool very slowly, when the wire is found to be soft, and capable of being easily bent, having entirely lost its springiness. It will, however, have upon its surface scales and oxide from previous heatings, and these have now to be removed. The coils are therefore laid in a pickle of sulphuric acid and water, which is made very weak, or it would soon wholly dissolve the iron. A little copper is sometimes placed in the solution, as the thin coating of this metal which forms upon the wire is considered to facilitate the "drawing;" but this is one of those details on which manufacturers are not agreed. After coming out of their pickling-tanks the coils are washed in beer-grounds, which further clean the surface, and prepare them for the operation of the draw-plate. Imagine a long room or workshop, with a bench extending the whole length of it, at one end of which are two short, stout uprights, against which leans the draw-plate (fig. 13). This draw-plate is of steel, or iron faced with steel, and has a number of conical holes drilled through it, round, square, or triangular, according to the proposed section of the wire.

The wire to be drawn is generally laid at one end of the bench, in a tub of beer-grounds, close by the draw-plate

One end is filed to a point, and is passed through the plate far enough to be seized by a pair of pinchers or grips attached to a chain, which chain is itself made fast to a lever something like a pump-handle. By means of this it is drawn little by little through the largest hole in the plate, until a sufficient length is obtained for the grip of another pair of large nippers. The latter are also

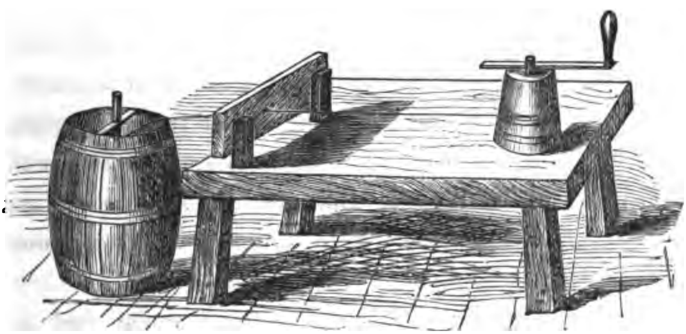

Fig. 13.

attached to a chain, and are dragged forward by steam-power. The wire is thus forcibly drawn through the steel plate, and reduced to the size of the largest hole. Again and again it is brought back, and passes in turn through smaller and smaller holes, until it has attained the fineness required. It is, however, necessary to anneal it afresh after each drawing in precisely the same way in which it was annealed after leaving the rolls, namely, by heating

it in closed cases, and allowing it to cool very gradually. At the last drawing, however, it is very frequently left bright and hard, as for some purposes it is better in this state.

I have given the mere outline of wire-drawing in this chapter, but it will, I think, suffice to give my young readers an insight into this important manufacture. It may easily be conceived that for iron to stand all these processes without snapping off, the quality of the metal must be extremely good. This is the reason it is smelted with charcoal, as coal, which might be used instead, contains sulphur and arsenic, and other impurities, which render the iron more or less brittle and unequal in texture, and though suitable for other purposes, renders it utterly unfit for wire.

At the time of our visit to Tintern steam had not usurped the place of water as a motive power, but the hand draw-plate was even then only used to get a sufficient length of wire to attach to the drum worked by powerful machinery. This is still its only practical use; and indeed for this purpose it has for the most part been displaced by self-acting tongs, which are themselves drawn along the bench by a powerful chain, until enough wire has been dragged through the hole in the draw-plate to allow it to be taken hold of by the clip attached to the surface of the drums, which latter are now made to revolve

by steam-power alone. Watchmakers and goldworkers, who often need fine wire of the precious metals, draw down for themselves the coarser wire, merely placing a draw-plate in the vice, and pulling the metal through the various holes with a pair of pliers. In this way they easily obtain short lengths of half-round, triangular, or square sections, as required for various purposes of their trade. Wire made of brass or copper is treated in a similar manner to iron wire, so far as its general manufacture is concerned, any difference in detail being due to the peculiar nature and quality of the metal used. Zinc and lead are also now obtainable as wire, chiefly for horticultural use, as they are very convenient for tying up vine shoots, and training roses and other plants, the strength of the fingers sufficing to twist the metal without the intervention of pliers.

CHAPTER V.

BRASS TUBES.

FEW people would guess the mode in which brass tubes are made in the present day, still less would they suppose that the process of their manufacture is akin to wire-drawing, of which we treated in the last chapter; yet so it is, and they can now be made either parallel or taper of almost any required length, and as smooth internally as they are on the outside. A very little consideration will prove that a very large number of brass tubes are used in our various manufactures, as, for instance, in locomotive boilers, condensers, astronomical and philosophical instruments, curtain-poles, gas-chandeliers, lamps, and so forth. In old times only one way of making these was known, namely, by folding thin sheets of brass over a mandrel or round bar, and soldering or brazing the seam. They are now made in vast quantities by casting

and drawing, so as to be wholly without seam, and can be made of any size required, down to one-fourth of an inch in diameter. Brass, it must be remembered, is a compound of copper and spelter (zinc), melted together in an air-furnace. The operation is one requiring great care, because zinc evaporates, and passes off as vapour, under a temperature that will not melt copper. The crucibles in which the melting is effected are therefore closely covered and secured by a plastering of clay. As soon as the copper is sufficiently hot to absorb the fumes of zinc, the two metals combine, and, it may be remarked, metals thus combined frequently melt afterwards at a lower temperature than would have sufficed to liquefy the less fusible of them alone. This is the case with brass, which also improves in quality by being melted again and again. Consequently the founders always mix a certain proportion of old brass with the spelter and copper which is to form a new supply.

To cast a hollow tube there are required a flask or iron box of the length of the tube, with a round recess or hole from end to end when closed, and also a core or cylinder, so laid that the metal may flow round it. The external surface of this core must have the form that the interior of the tube is to have: in the present case it will therefore be cylindrical.

In fig. 14, A is the flask closed, B the core, C the

interior of the half flask. The latter, when closed, is secured by iron clamps EE. The cores consist of a rod of iron upon which are layers of clay, or rather of sand and loam ground together in a mill, and made into a paste with water. The method of making these cores is simple, but exceedingly ingenious. The iron rod is supported at each end in what may be called two little iron forks, at the ends of a bench. The rods being

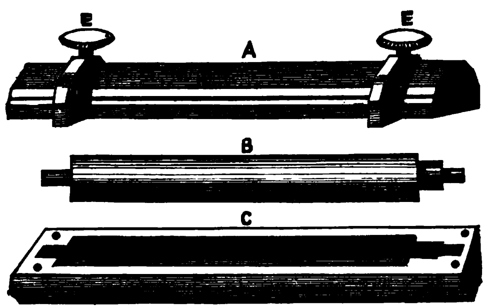

Fig. 14.

squared at the right-hand end, a handle is slipped on, which is turned by a lad while a handful of hay is held against it, which is thus neatly coiled like a rope upon it, from end to end. The wet loam is then plastered on it as it continues to revolve, and is smoothed and rendered of the exact cylindrical form by bringing up against it the edge of a board which rests upon the bench behind it. When one coat of the loam is dry, another is put on, and

the cores are ranged in a hot chamber, where they become sufficiently hard to bear the pressure of the heated metal. At one end of the flask is a recess to receive one end of the rod, the other resting in a similar recess at the opposite end, where room is also left for pouring the metal, which is done with the flasks placed upright. The end of the tube where the pouring took place is not generally so sound as the rest, and has also a kind of lip of metal attached; but this is cut off by means of a circular saw before the next operation is begun; and as boys like noise, this sawing ought to suit them exactly.

The cores are of course broken to pieces in removing them from the tubes, and are ground up and mixed with fresh loam. The tubes, which are not very rough, are placed in a pickle or bath of sulphuric acid and water, which cleans the surface by dissolving a small portion of the metal. They are now ready for drawing, which is performed as follows:—A long bench of massive proportions has a broad and strong chain passing over rollers at each end of the bench, and continued underneath, where the ends are fastened together, so that it becomes one continuous band. The rollers are cogged, so that there can by no possibility be any chance of the chain slipping, and they are kept revolving by a steam-engine. At one end of this bench is an upright rest for a steel die, conical on the inside, the small part of the cone

being next to the bench. Through this die the tube has to be forcibly dragged. To effect this it is first placed on a mandrel turned for the purpose, with a shoulder near one end. Fig. 15 shows *aa* the tube slipped over the mandrel *bb*, *cc* the die in section. *d* is a cross-bar by which the mandrel is attached to a kind of clamp, so made that it will lay hold of the chain at any part on which it is placed. Thus, as the chain passes along the table the mandrel is carried with it,

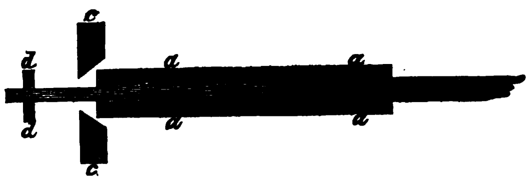

Fig. 15.

and the tube is forced to pass through the steel die, which reduces its size, and considerably lengthens it. By this operation the brass is rendered smooth, but very hard and brittle; and before it can be further reduced it requires to be annealed, by placing it in a furnace, and heating it to a dull red, allowing it afterwards to cool very slowly. It is then drawn again through a smaller die, and so on until reduced to the required size. During these operations it will be lengthened perhaps from four feet to twelve or more, remaining in

all probability perfectly sound. This last point, however, is of great importance, and the tubes are tested by a jet of steam at fifty pounds' pressure admitted inside, while the ends are plugged, or by filling them with water at a similar pressure. Any flaw, even if invisible to the eye, is at once detected by the escape of the water or steam. During these operations the tubes very often become slightly bent, and they require to be straightened before being packed for the market. The straightening is rapidly done by a boy, who merely passes the tube through a hole in an upright post of wood, and presses it in the required direction. This seems but a clumsy mode of proceeding, and is in fact identical with that followed by the broom and mop handle makers. It is, however, not only perfectly effectual, but is, probably, the only way in which this work could be managed. Such is the process by which thousands of tons of solid tubing are made every year, ready to pass into the hands of those who give them their required form. A very large quantity are used for gas chandeliers and lamps, being variously chased and ornamented. Telescope tubes, which fit so exactly inside each other, show with what accuracy it is possible to draw the different sizes. If they are to be bent, as for cornopeans and other musical instruments, they are first filled with sand, or with soft solder that can be subsequently melted and poured out.

IRON TUBING.

Brass being far more costly than iron, the latter metal is also largely used for tubes, some of which are cast, such as stack pipes for house roofs and for gas; but as these are brittle, and unsuited for purposes in which toughness and strength are necessary, means have been discovered for welding them from plates or strips of wrought iron. It may, perhaps, not be known to our younger readers that the properties of iron in the conditions of cast and wrought are very different. The first breaks easily, and the fractured parts reveal an aggregation of bright crystalline grains, coarse or fine, according to quality. By remelting, puddling, hammering, and rolling, these crystals become drawn out into fibres, the metal becomes tough and malleable, and may be drawn into wire, beaten or rolled into thin plates, and welded—that is, at a heat a little below that which would burn the iron it will unite under the hammer, and be as sound at the joint as elsewhere. Iron in this state cannot be remelted; but when raised to a high temperature it burns, and throws off showers of brilliant sparks. There is, however, a peculiar property which belongs to wrought iron which is not so generally known, except to engineers and men of science. A bar, suspended and continually hammered, so as to keep up constant vibration, will pass

into a partially crystalline condition, and break—sometimes falling apart spontaneously. In railway bridges the wrought-iron girders sometimes attain a similar state from the vibration produced by passing trains, and accidents have not been unfrequent from this weakening of the structure.

The iron for tubes must be of good quality, and is rolled

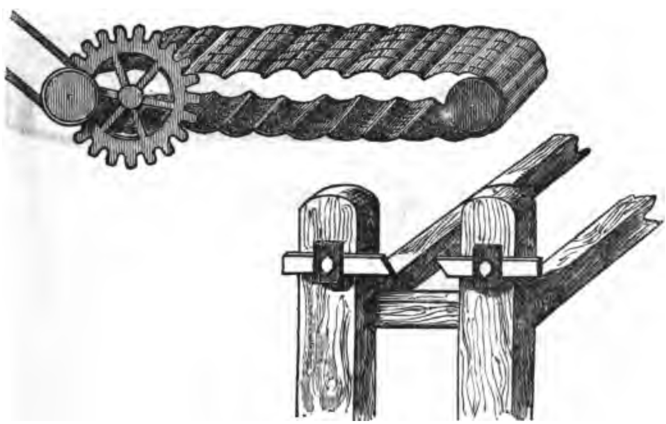

Fig. 16.—Bevelling.
(The drawing of the flat chain does not show the links sufficiently open.)

first into sheets, which are afterwards cut to size between slitting rollers. It is now necessary to bevel each edge somewhat, that when welded there may be no raised seam. This is effected by dragging the strip, by means of a flat chain with a clamp attached, between a pair of tools fixed inside two strong uprights which rise from the bench at one end (fig. 16). The bench itself is very similar in

appearance to that used for drawing brass tubes, as already described. The iron is now ready to be folded, being up to this time merely a long flat plate. First it is subjected to the action of a kind of hammer with a convex face below, similar to fig. 17, the plate lying upon a hollow bed, which represents a mould of the lower half of the tube. By this operation it is made to assume a semi-cylindrical form.

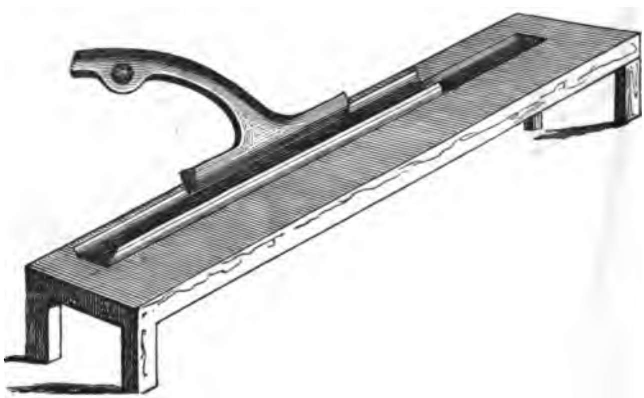

Fig. 17.

Further hammering lays the two edges neatly together from end to end, the bevelled parts overlapping. The tube now has to be welded, which is very ingeniously managed. The difficulties that had to be contended with were great. It was necessary to have a rod or mandrel inside to bear the strokes of the hammer, or the pressure of the rollers used instead of hammers; but having welded

a tube upon such a bar, the difficulty of withdrawing it would be insurmountable. Moreover, a welding heat must be kept up until the whole seam is complete and sound. These difficulties have been met as follows :—The folded

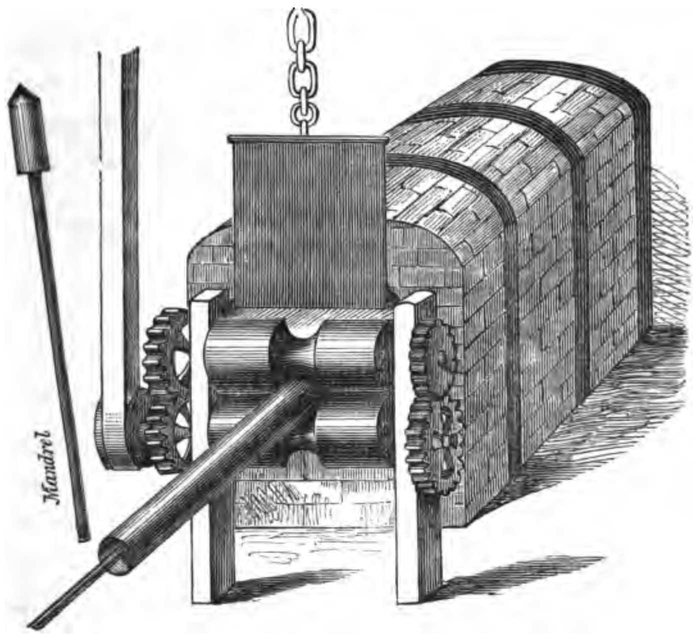

Fig. 18.—Furnace and Rolls.

tube is placed in a long furnace (fig. 18), the seam having been previously sprinkled with sand, which, melting and forming a glaze upon it, prevents in a great measure both sealing and burning.

Close to the mouth of the furnace are a pair of rollers, set in motion by steam, with grooves or channels upon their surfaces, which together form a round hole of the exact size of the intended tube. These form the compressing power by which the weld is made. The mandrel for the inside consists of an iron rod considerably less in size than the tube, but on the extremity is a short piece which fits the inside of the tube. This is placed between the rollers, so that as the tube is drawn from the furnace it must of necessity pass over it. But as this mandrel fits the tube, it would be carried along with it as it emerges from the rollers. To prevent this, two men with sledge-hammers keep on hammering the other end of the rod to which it is attached, so as to keep the mandrel in the right position between the rollers, and prevent it from being jammed and fixed in the tube. The last blow given drives it out of the end, when the process is complete. It is very rapidly performed; and the tubes are so arranged that the moment the mandrel is withdrawn from one, there is another at welding heat ready to be operated on. These iron tubes are used in boilers and elsewhere instead of brass, when the latter metal rises considerably in price, as is very often the case.

There is one notable peculiarity in the manufacture of iron and brass in the present day which steam has enabled us to adopt, viz., the use of rollers instead of hammers

for forging. There is, indeed, a steam-hammer of stupendous size commonly used in ironworks, but it is adapted for the heavier and more massive objects, as, for instance, anchor-making, and welding the huge coils of iron for the Armstrong guns. It is also used to reduce the blocks of iron from the puddling-furnaces to thick plates, as well as for many other purposes. There is also a steam-hammer or forge, giving almost any number of light blows per minute, which is used at the Small Arms Manufactory near Birmingham, and at Enfield, and I dare-say at many other places. I cannot now recall its name, but it is a very clever piece of machinery, and rattles away at an amazing pace, wholly superseding for some purposes the hand-hammers previously used. The roller system is, however, far more serviceable for work such as I have described, because we have only to turn grooves of any desired shape on the surfaces of the rollers, and then any bar, rod, or tube made to pass between them as they revolve (the metal being, of course, softened first of all by heat) must receive an outside or superficial form agreeing with the shape of the grooves. All the rails, of whatever form, used for the permanent way of railways are thus rolled, and could not be formed otherwise; because if they were cast in moulds, the metal would be quite brittle, whereas if formed by rolling, it is fibrous, and exceedingly tough.

The "roller system," as it may well be called, has in fact of late years swept out of the way many older contrivances, and is so simple and so effective that it will always keep its place in our manufactures. It is now used in printing-presses to give impressions of the type—the paper passing over one set of rollers and under another as they revolve above the forme, or frame in which the type lies, so that both sides are printed almost simultaneously. The forme passes to and fro under other rollers whose surfaces are charged with ink, while another set deliver the paper in sheets at one side of the machine. Calicoes are similarly printed, by passing over and under rollers on which the required pattern has been embossed. Paper, too, which is composed of pulp made from rags, straw, and other substances, is first of all little else but a sheet of thin and loose felt; but as it passes in its course between rollers which press out the water, it gradually becomes drier and more compact, and is eventually wound off on another roller in one continuous and firm sheet, which is afterwards cut and sized, and otherwise finished, as may be required. If the illuminated or ornamented paper is needed for wall-decoration, this is also now done in the same way as the calico is printed, whereas in old times it was entirely worked by hand with square blocks on which the pattern was carved. These were covered with a layer of the necessary colour, and pressed on the fabric, great care

being necessary, in applying consecutive blocks, to produce a continuous pattern without apparent joins or seams.

I believe that corrugated iron, now used so largely for roofs and portable houses, as also perforated zinc, in which there is a continuous repetition of the same pattern, is made by passing the metal, in the first case, between rollers with grooved or wavy surfaces, and in the second, between pairs of rollers with pins of any desired form in the one, and similar indentations in the other, which would be, in fact, continuous punching. And in every similar case where a pattern is to be repeated again and again upon long sheets and strips of metal, rollers afford the readiest method of producing the work. It is probable that the use of rollers for corrugating and fluting metal was suggested by the crimping-irons of the laundress, which consisted of two rollers made hollow to contain heaters, and fluted on their outer surfaces; these, turning in contact with each other, frilled or corrugated the material as it passed between them. There are many other manufactures in which rollers are similarly employed, but these suffice to show their general application. Moreover, one great advantage is that the machinery to actuate them is of the simplest character, and not liable to get out of order; and there is no shock in their use, and consequently no excess of wear and tear. The shock of stamping machinery, on the other hand, is always great,

and the expense involved in repairs proportionally heavy. Our readers should try and visit some one of the various ironworks and rolling-mills in the Black Country in the north of England, and they would thus see for themselves the prodigious power obtained by machinery of the above character. It requires a painting to give any idea of the effect of the iron furnaces and large works of the kind; the pen and graver are powerless to give it expression.

Chapter VI.

MECHANICAL ARRANGEMENTS.

BEFORE entering further upon mechanical processes, it will be as well to explain the principles upon which all machinery is constructed, whatever its special object may be. It was indeed my intention to leave this for a concluding chapter, but "second thoughts are best," *as people say*, and I shall place it here instead. *As people say*, is nevertheless hardly a safe dictum, and I am by no means sure that second thoughts *are* best, as a rule. With some rusty, crusty people, who have to think at least twice before they can make up their minds to give a copper to the poor, or with some irritable, bilious, old fogies who are always imagining that people want to insult them, and who immediately let fly the topmost word from their internal reservoir of growls, second thoughts *are* best—at any rate, they cannot well be worse than the first. Not so with noble-minded, generous-hearted boys, always

ready to do a kindness without counting the cost. I like a boy who cannot always stay to balance *pros* and *cons*, but with whom kindnesses are ever ready, waiting opportunity only for their exercise. With these, first thoughts and first impulses are decidedly the best, although a cold world may pronounce against their wisdom. It is better to give to a humbug than to refuse a genuine object of charity; better once in a way to feel that you have been "done" than to find out that you have failed to do a kind action from too nicely arguing with yourself the worldly wisdom of the same. If the heart is good and honest and free, depend upon it good and Christian impulses are upward; and I say, boys, never check them, but let them tumble out as they will, and don't wait for second thoughts.

Mechanical arrangements, however, *do* require second thoughts—ay, and third and fourth, and many more. Much consideration and deep study is often needed before the crude idea, however excellent, can be worked out into a practical form. The first necessity is a knowledge of the principles of levers and cams and eccentrics, and suchlike; what they will do, and what no contrivance will make them do. Scores of otherwise rational, and even clever people, have spent time and toil and money in trying to circumvent mechanical laws, and compel 1 lb. to act like 2 lb., or a 6-foot lever to become alternately, as regards

its power, 6 feet and 3 feet, and thus, as they fondly hope, startle mankind with "perpetual motion." But, boys, it is no use to work at any such fallacy; and when it is considered that the Almighty Himself made all the laws of nature, physical laws and mechanical laws alike, it is not the least likely that any human being will be able to upset them, and it can only be folly to attempt it.

We will begin with levers, which are nothing but rigid bars, straight or curved, as the case may be, but absolutely *inflexible*—that is, cannot be bent. Now this, to begin with, is a theory that cannot be wholly carried out, because levers *do* bend; but you must for the present suppose that they do not.

Let the line AB (fig. 19) represent a straight bar of iron or wood turning on the point C, which may be the upper edge of a stone, or anything else that will support it in a similar way. If the part AC is exactly the length of CB, like the arms of a pair of scales, it will require a force of 1 lb. applied at A to lift a weight of 1 lb. resting on B. Here, therefore, you get no advantage in the way of *power*, only perhaps it may be more convenient to pull down A than to lift up B. It is frequently so in machinery. Now let AC (fig. 20) be twice the length of CB, and

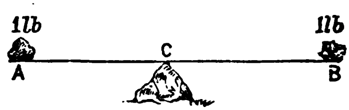

Fig. 19.—Lever.

let 1 lb. still lie on B. You will now find—for you should prove this for yourselves—that a force or weight of $\frac{1}{2}$ lb. at A will raise the weight. Here you have gained apparently a great deal of power, and practically you have done so.

But let us go a step farther. Suppose you have to raise the weight 1 foot high, you will find that it will be necessary to depress the longest end of your lever 2 feet, exactly double the distance. Hence you may say it took $\frac{1}{2}$ lb. of weight or power to raise the weight the first 6 inches, and $\frac{1}{2}$ lb. to raise it the other 6, and in reality you have used a power of 1 lb. to raise 1 lb. In short, take it as a standing rule that *you cannot create power*. All you can do is to make the most convenient use of such power as you have.

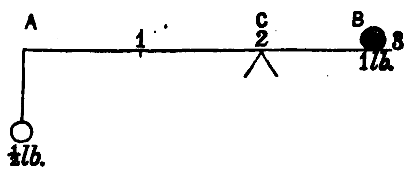

Fig. 20.—Lever.

Now put the fulcrum or support of your lever in a different place. Let the bar rest with one end on such support, and hang the weight as before, fig. 21. One pound applied at A will lift 3 lb. suspended at B; but to raise the weight 1 foot, the end of the longest arm will have to rise 3 feet. So that here again the apparent gain of power is a fallacy.

But why in the second case is the apparent gain three to

one, and in the first case two to one? Simply because the rule of leverage is this:—The power to be applied is to the weight to be raised exactly in proportion to the distance of the weight from the fulcrum compared with the distance of the power from the fulcrum. Or if we regard it as a question of balance, which is perhaps the

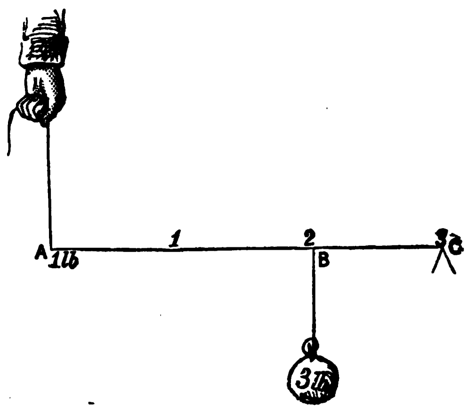

Fig. 21.—Lever.

easiest way—"*The weight (or resistance) multiplied by its distance from the fulcrum must equal the power multiplied by its distance from the fulcrum.*

Thus in the first case, which is a lever of the first kind, we have a weight or resistance of 1 lb. at a distance of 1 foot from the fulcrum, and $1 \times 1 = 1$. We have a power of $\frac{1}{2}$ lb. applied at a distance of 2 feet from the

fulcrum, and $\frac{1}{2} \times 2 = 1$. In the second case, which is a lever of the second order, we have the weight of 3 lb. at 1 foot from the fulcrum, and $3 \times 1 = 3$, therefore we need a power of 1 lb. at 3 feet from the fulcrum ($1 \times 3 = 3$). I have treated lifting-power and balancing-power as the same thing, but of course a little more power has to be used to produce motion. We have in addition to these levers another of the third order, in which the power is nearer the fulcrum than the resistance or weight. In this case, we have *more* work laid upon us, for the leverage is against us.

Let us again suppose a 3-lb. weight hung at B (fig. 22).

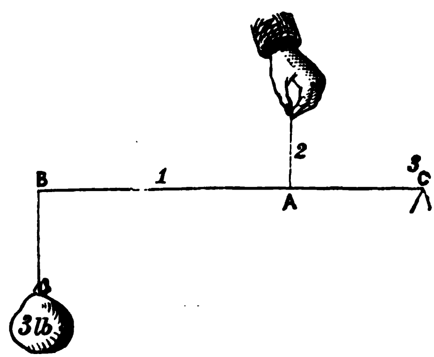

Fig. 22.—Lever.

It is 3 feet from the fulcrum, and $3 \times 3 = 9$. The power is applied at a distance of 1 foot from the fulcrum, we therefore shall require a force of 9 lb. ($9 \times 1 = 9$) in order to get the

balance correct as before; that is, the leverage is as three to one against us. But this loss is not without its equivalent gain, for whereas in the previous cases we had to move the power through a long distance to raise the weight a little way, we now have only to move the power a short distance to raise the weight a long one, *and in the same proportion.* So that levers neither create power nor lose it, but only supply means for the convenient application of it. You must notice the real difference between these three kinds of levers, and I think you will thoroughly comprehend this first prime law of mechanics. In levers of the first order the power is on one side of the fulcrum, and the resistance on the other. In the second, both are on the same side, but the resistance is nearest to the fulcrum. In the third, power and resistance are still on the same side, but the power is nearest to the fulcrum. Now for a step further.

Let us try two or three levers in combination and see the result. Here in fig. 23 A we have two levers both with equal arms, these may be any length, and it is not necessary that both should be alike, but the arms of the first are to be equal, and likewise those of the second. Then a pressure of 1 lb.

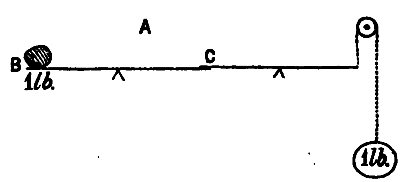

Fig. 23.—Lever.

at B will raise 1 lb. at C, or press the arm of the second lever upwards with a force of 1 lb., and the other arm will be pressed down with equal force, raising 1 lb. suspended, as shown. There is no gain here in any way, but again, in machines, and notably in the key action of organs, double levers like this are very much used; and wherever we have not room to make use of a single long lever, this combination will be very convenient. But this will be more apparent when instead of equal armed levers we use those which form levers of the first or second order, as in the following combination.

Here (fig. 24) E is a cord, CD is a stiff rod. Keeping still the same length of lever as before, 1 lb. pressure on the upper and longer arm will raise 2 lb. at E, pulling up the long arm of the second lever with that force. This will push down D with a force of 4 lb. and a weight of 8 lb. will be raised at F.

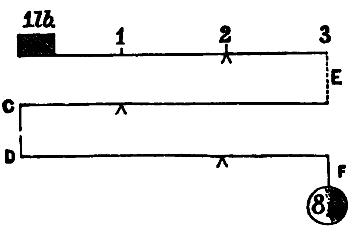

Fig. 24.—Lever.

To have effected this with a single lever, we should have required one 8 feet long, suspended or supported at one foot from the furthest end. The rule before set down of course will apply here. The weight is 8 lb. at 1 foot from the fulcrum, $8 \times 1 = 8$. The power is 1 lb. $\times 2 = 2$; 2 lb. $\times 2 = 4$; 4 lb. $\times 2 = 8$; the sum of the powers equalling the sum of the resistances.

Now, I daresay my young readers will not at first see the similarity between cogwheels and levers, yet, as mechanical powers, they are identical.

A wheel mounted on an axle is in fact only a perpetual or continuous lever, of which the axle is the fulcrum. If we make our wheel with spokes we shall see this quite clearly. As the axle is generally in the centre of the wheel, we shall not gain any leverage by merely allowing one to work into the other, unless we also make some special arrangements.

Here in fig. 25 is a large wheel working into a small one, which last is called a pinion. The spokes *a*, *c*, *b*, *e*, *d*, including the cogs, are, as you will at once see, only our old friends, levers of equal arms of the first order. 1 lb. suspended at *a*, will balance one at *b;* and one at *b*, the end of the spoke of the small wheel, will balance one at the end *d*.

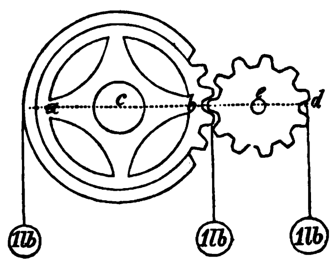

Fig. 25.—Cogwheels.

But though a wheel is of necessity a lever of equal arms, we can make it practically a means of power; and with this further advantage that the power is continuous. In fig. 26, the large circle represents a wheel; let it be 24 inches across, from A to D.

Fixed to it let there be a small pulley BC, or let BC represent a stout axle. Now we thus obtain a lever AC, moving on a fulcrum B; but AB is much longer than BC, say four times as long, then by our old rule a weight D, of 1 lb. hanging from it, will balance a weight of 4 lb. suspended from C, and if the cords are wound round the wheels, we can by uncoiling the one, using a continual force of a little over 1 lb., wind up the second with its weight of 4 lb. This facility of continuing the power over an unlimited space gives to the wheel and axle its advantage over a simple straight bar. Each spoke, in fact, becomes a lever in turn, and we can imagine these so close together that there is no cessation of their action.

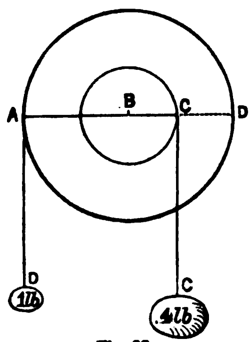

Fig. 26.

In the next combination, represented in fig. 27, we have again compound levers. The pinions or small wheels are fixed to the axles of the larger ones, so as to revolve with them. Let the first wheel AE be 4 feet diameter, and the small one fixed to it 1 foot diameter. This works into the edge of the second wheel, which is, we will suppose, 2 feet, and carries on its axle a pinion of 6 inches. The first lever will be AD, turning on its fulcrum C; the long arm will be 2 feet long, the short one 6 inches. Therefore a power

of 1 lb. at A will become four times as great at D, the circumference of the pinion (for $4 \times 6 = 24$ inches or 2 feet). This force, thus already quadrupled and therefore equal to 4 lb., is applied (by moving the wheel) to the long arm of the lever DG turning on the fulcrum F (the axle of the second wheel), and as the pinion is only 6 inches diameter, the short arm of the second lever is but 3 inches. The power is therefore again quadrupled and becomes equal to 16 lb., which is the weight balanced at the end of the second lever. Thus, so long as motion is continued we gain in the proportion of 16 to 1, and in the simplest manner possible. You can always get at the proportion of power to resistance in wheels and pinions by sketching only the spokes which lie in a horizontal direction, and considering them so many levers acting upon each other. But the similarity between wheels and levers does not end here, as we shall see presently; for if we gain apparently a power

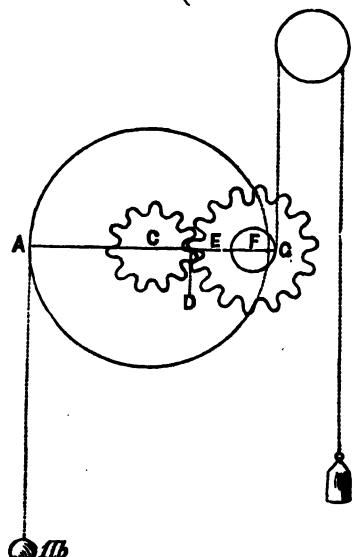

Fig. 27.

of 16 to 1, you may rest assured we have exercised that power through a distance sixteen times as great as that through which we have raised the weight; and if the weights are suspended from ropes coiled round the rims of the wheels, we shall have uncoiled no less than 16 feet to raise the weight 1 foot. There is positively no way of circumventing this mechanical law. We will not continue this just now, but speak of velocity or speed. Ah! perhaps here we shall be able to manage better, and really gain something! Not a bit of it! the moment we increase speed we lose power, and if we have only a given force to work with, and have to raise a weight many times greater, we shall find it possible to attain that end only by doing our work very slowly indeed. Keeping, however, this law before us, we may arrange so that a child may raise a ton.

A wheel of 2 feet diameter, working into one of 6 inches, will evidently turn it round four times, while itself makes but one rotation, the cogs being supposed to be in number as 24 to 6, or 4 to 1. Dispensing with cogs, and allowing the wheels simply to touch, and thus move by "rolling contact," as it is called, the same rate of motion will be obtained, and the surfaces thus in contact represent what is called the pitch line upon which the cogs are set out. If we could prevent slipping, the rolling contact would be preferable to cogs; and there

are some machines in which it is used. Of course it is a perfectly silent action, whereas that obtained by cogs is very noisy.

Now, if you take any one point on the circumference of each of your two wheels (or wheel and pinion), and measure from it, quite round the wheels, you will find the length about three times the diameter, in this case 6 feet and 18 inches respectively. The end of your lever, therefore, will make a circular journey of 6 feet, and in so doing will move the end of the short lever also 6 feet; but the latter will have to run at a much higher rate of speed to accomplish its distance in the same time—like the child, taking perhaps three steps to one to keep pace with its father's strides.

Another rule of mechanics which both the lever and the train of wheels exemplifies is this, *To gain power you must be content to sacrifice speed, and if you gain speed you lose power.* I shall conclude this chapter with a drawing of a train of wheels (fig. 28), which I think will make this quite clear.

In this figure let A, B, C, be three wheels of equal size—say 2 feet diameter, or 6 feet in circumference—and let the two pinions D, E, be each 6 inches diameter, or 18 inches in circumference. The last has a handle H attached at the extreme edge to give motion, and we will apply here a force of 10 lb.; as the pinion is one-fourth the size of

the wheel, we must at once multiply 10 by 4, which is the power applied at the circumference of the second wheel. This again multiplied by 4 gives 160 lb. applied at the circumference of the third, and if this last has an axle of 6 inches diameter from which a weight is suspended, we

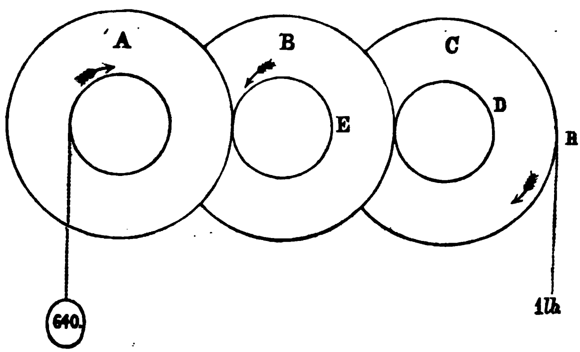

Fig. 28.—Train of Wheels.

may again multiply by 4 and find that 640 lb. may thus be raised. The power gained is thus very great, but let us inquire as to speed.

While the first wheel is turned once by its handle carrying its own pinion once round, the latter will only move the second wheel one-fourth of the way round; its pinion will therefore likewise move only that distance: or, if the large wheels have eighty teeth and the pinions twenty, one turn of the first will have only caused the second to advance one-fourth of eighty, or twenty teeth,

and its own pinion five teeth. As these five teeth are in gear with the next wheel, this will have moved but five teeth, or just one-sixteenth of its circumference. Its axle is 18 inches in circumference, and this will have likewise moved only one-sixteenth of its way round (or revolution), or one-sixteenth of 18 inches, *i.e.*, $\frac{18}{16}=1\frac{1}{8}$ inch, which is the height the weight will rise during each revolution of the handle. The distance the latter has moved, of course, equals the circumference of the wheel to which it is fixed. It has moved 6 feet, or 72 inches, in order to raise the weight $1\frac{1}{8}$ inch.

Now see once more how nicely our principle of levers works out and balances. We applied a power of 10 lb. and it raised 640 lb., or sixty-four times its own weight. But this power travelled 6 feet, or 72 inches, to raise the said weight $1\frac{1}{8}$ inch. If you work out the sum you will find that 72 is just sixty-four times $1\frac{1}{8}$ inch, thus—

$$1\tfrac{1}{8}\text{ inch} = \tfrac{9}{8},\text{ and } 72\text{ inches} = \tfrac{576}{8}$$

We can knock off the denominators, as they are equal, and we have

```
9)576(64
  54
  ──
   36
   36
   ──
```

There is nothing more beautiful than the way in which the balance of leverage works out in all cases. If you

gain ten times in power, you lose ten times in speed, and *vice versâ;* and *if* you can get over this and gain power and speed at once, you will not find it so exceedingly difficult to obtain—perpetual motion,—but that little word "If"!

CHAPTER VII.

MECHANICAL POWERS.

ALTHOUGH a great number of mechanical expedients are but combinations or peculiar arrangements of levers, there are one or two others that I think should be illustrated before going into further details. The first is the wedge. This consists of one or two inclined planes, and when an inclined plane is made continuous and coiled about a cylinder we obtain a screw, one of the most generally serviceable of all these powers.

Let us inquire into the peculiarities therefore of the inclined plane. Here it is in fig. 29, A, B, C. This may represent a board at an inclination, for purposes of experiment, or a hill; and I want to make it clear to you that in walking up that hill, you do precisely the same amount of work, whether you walk up the long plane AC, or the shorter and steeper one AD, or get

up BA as best you can. You have, in short, in all cases, to raise a certain weight—that of your body—or a stone, or something else, from B to A. Now, I will venture to say that if the path AC were a winding path round a hill with gradual ascent, and AD a steep and awkward path by bush and tree, you boys would go up the latter, and I, the old fogey, should decidedly go

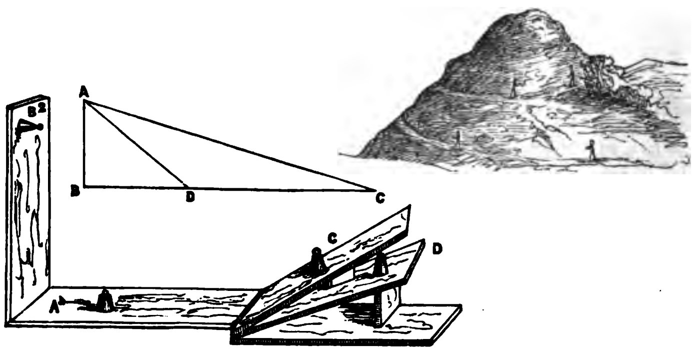

Fig. 29.—Inclined Plane.

the longer round; anyhow, we should lift our bodies the height AB, but I should expend a *little* power over a *long* distance, and you would expend *greater* power over a *short* distance, which is uncommonly like what we discovered about the levers in our last chapter. To understand the nature of this mechanical power, suppose a weight of 10 lb. to rest on a level board, its effective weight would be 10 lb. Now, if you were able to raise

the board to a vertical position (placing it on its end) without allowing the weight to fall from its surface, such weight, as regards its pressure upon the board, would be nothing. The first case is shown at A^1, the second at B^2. Then it stands to reason that the nearer the board lies to the level position the more weight it bears, and the nearer it is to the vertical the less. Thus it will bear more weight at D than it does at C. If I were now to tie a string to weight placed at the bottom of B, and lift that weight by its means the height of the plank, I should simply lift the whole weight, exerting a power of 10 lb. without any assistance derived from the board, which might as well not be there at all. But if I were to put the same weight on the board and incline it as at C, the board would bear a portion of the 10 lb., and I should have to exert less power; or if, lastly, the board were very slightly inclined, it would carry more of the weight, and I should have less to raise. In all practical cases of friction (or rubbing) between two, the surface has to come under consideration, as it forms an element of resistance, but this may be neglected in such a mere sketch of science as the present. Obviously, then, the more gentle the inclination of the board, the more it assists me in raising a weight to the highest end of it, because it relieves me of a portion of that weight. That there is a simple rule in the matter, the foregoing remarks

will abundantly show, and these we will now investigate. Fig. 30 represents a plane raised at one end 10 feet, the sloping surface of it being 100 feet in length. At every 10 feet we may draw a perpendicular line, and by drawing horizontal ones to meet these we make ten steps, and evidently the rise or height of each will be 1 foot, as the whole ten make up together a rise of 10 feet. As long as we are on the level of the steps, the weight is wholly supported, and it is only at the perpendiculars,

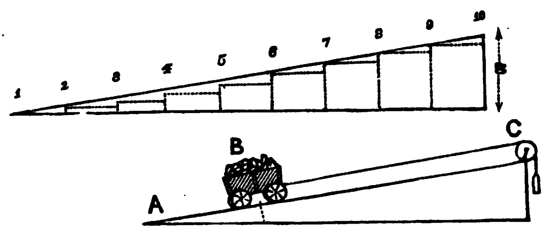

Fig. 30.—Inclined Plane.

or "risers," that we must lift our 10 lb.; we shall therefore lift it 1 foot, and repeat this ten times, which is the same as lifting it 10 feet at once. The former would be certainly far easier. Doing away now with the steps, but keeping the incline, the weight, at any given point on that incline, exercises one-tenth of its entire pressure, or 1 lb., and, with a plane constructed as here, a force of 1 lb. would balance its weight; but we drag our 1 lb. 100 feet, $1 \times 100 = 100$, or we may without the plane lift the 10 lb. 10 feet, $10 \times 10 = 100$.

If you make a little truck which will run easily upon a pair of miniature rails, and arrange your incline by hinging it at the angle so that you can raise or lower it, you can prove this by experiment; but remember you will require rather *more* than the calculated weight to overcome the friction, because, however smooth your rails and well made your truck, it will not run quite easily. Upon a level rail a truck of 1 ton weight can be *theoretically* moved by a power of 8 lb., *practically* it may need 10 or 12, or even more. We have, however, now attained a standard or unit of work for the inclined plane. The weight multiplied by the height, together representing the resistance, will equal the power multiplied by the length of the plane. Here it is as stated, 10 lb. × 10 feet = 1 lb. × 100 feet.

The wedge as commonly made consists of two such planes, but the rule is here, again, that the less the inclination of its sides the greater is the power, or the longer it is in proportion to its thickness the easier will the work be done by its means.

I should state here that the above calculations are true only when the power is exercised in a line parallel to the incline—as, for instance, by means of the rope in the drawing; and remember also that the *direction* of the weight borne by an inclined plane is perpendicular to the surface of that plane. In B, of this figure, for example,

the direction of it is shown by the dotted line. In like manner the direction of the force of a wedge C (fig. 31)

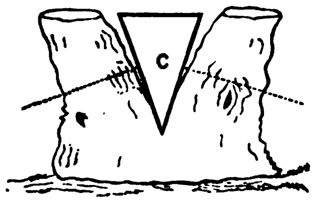

Fig. 31.

is perpendicular to its sides, which force tends to split the block into which it is driven. The whole question, however, of the "resolution of forces," is one too complicated for full discussion in these pages. We shall now therefore proceed to turn the wedge into a continuous force by making it into a screw, just as we converted the lever into a wheel.

If we cut out of paper an inclined plane 3 inches in height and 9 inches long, not on the base but on the inclined part, and wind it round a cylinder, we make a screw. This is, in fact, a spiral ascent round a steep hill. It makes no difference whether we wind it once round a large cylinder or many times round a small one, we still ascend an incline of 3 in 9, or 1 in 3, which is called the *pitch* of the screw. If you ever went to the top of the monument on London Bridge, or up a high church steeple, you know how delightful it is thus to screw your way upwards; and I suppose it is the tortuous walk of a drunkard that has suggested the term of "being screwed"—a widespread blot in the world, of which no genuine mechanical boy has ever borne the stain. Why a miser should be called an old screw is less clear. It is no doubt, however, a long and

tortuous path from the bottom of his pocket to its open mouth. The nature of the screw as a mechanical power will be easiest understood from noticing one or two applications of it. To make use of it we always require a nut, or block in which an internal thread is cut of the same pitch as the screw; and having this, we can use either as the actual source of power. For if the screw is so fixed

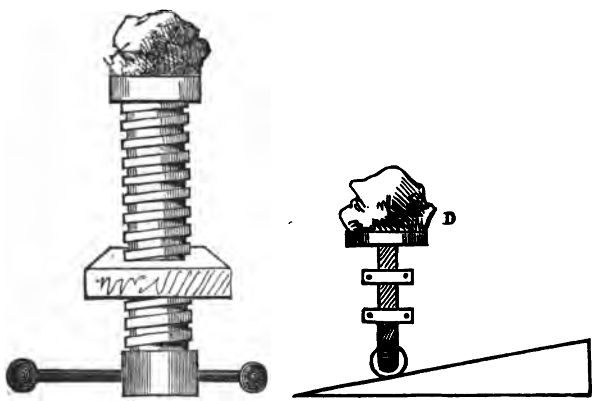

Fig. 32.—Screw.

that it cannot move endwise, it will, if turned, draw the nut along; or if the latter is fixed, and the screw permitted to travel lengthwise, the latter may be used as the interpreter of power, as in fig. 32, where, if we fix the nut and cause the screw to revolve, we can use the latter to raise the heavy stone. The screw-jack for lifting weights is constructed on this principle, and is in daily use by engineers

and mechanics. The rule is, that the finer the screw the greater will be its power. This we should expect, because a fine screw *uncoiled* would represent an inclined plane of great length in proportion to its height. A screw of the supposed pitch of one in three would do exactly the work of a wedge of the same dimensions in raising a given weight to a certain height. You might place the stone upon a platform D, free to rise perpendicularly by being passed through guide-bars, and by pushing the wedge along upon its base you would raise the stone. The little friction-wheel would be added in practice to reduce the resistance. But when great power is required, a very long and gently-inclined plane would be needed, which would in most cases be exceedingly inconvenient to use in practice. It is therefore wound round a cylinder, and converted into a screw, which takes up less room; and this, too, being turned by a lever-handle, a second power is brought into use, so that we can readily overcome heavy resistance in the form of weights or otherwise, as the case may be.

Now we come to the rule by which to calculate the power of a screw, and it is of course exactly that of the inclined plane. The total height to which the weight is to be raised multiplied by that weight, equals the power multiplied by the length of thread or the whole incline or spiral. In other words, as the height of the inclined plane

wrapped once round a cylinder represents the pitch from thread to thread, and the length of the plane is the circumference of the cylinder, the distance between the threads (or pitch) multiplied by the weight, must equal the circumference of the cylinder multiplied by the power, expressed in inches or feet, or otherwise; and hence, the less the pitch the greater will be the power.

The screw is used in many ways in addition to that of lifting weights, one common application being to move the slide-rests of self-acting lathes. These, which are arranged to carry the tool, slide the whole length of the lathe-bed, and the motion is produced as follows: To the under-side of the rest, which either projects between the bearers or hangs down in front, there is attached a screw-nut, which, however, is sawn into two parts that can be opened or brought together by a lever. Through this nut passes a screw, which lies along the lathe-bed from end to end, and turns in bearings which only allow it to rotate, but not otherwise to move. To one end of the screw a cogwheel is attached, which gears with others put in motion by the lathe itself. The result is, that when the screw rotates upon its axis it carries the nut, and with it the rest, along; but upon pressing the lever which opens and closes the two halves of the nut, the latter is released, and no further motion of the rest takes place. Great power not being necessary in this case, the

screw is cut with only two, three, or four threads to the inch, and of course it then requires two, three, or four revolutions to move the slide-rest (and with it the cutting tool) that distance. Sometimes, instead of a regular thread, either square or V-shaped, the cylinder has a groove traced spirally upon its surface, and into this a single pin, or perhaps two or three pins, arranged on a sliding bar, fall. On causing the screw to revolve, the pins are compelled to advance, and carry the bar along in a vertical, horizontal, or other direction parallel to the length of the screw. For a V-threaded screw, a mere row of similar notches in a flat bar are sometimes used as a nut, or a half nut only is used, but the action is similar in all cases.

I have sketched some of these arrangements in fig. 33.

The screw is so extremely valuable an arrangement of mechanical power, that an enormous amount of expense and labour has been expended in order to cut it perfectly. It is, among other uses, invaluable in telescopes, microscopes, and philosophical instruments, as affording means of providing motion in any direct direction in the minutest degree. In many mechanical contrivances, as, for example, in ornamental turning, it is necessary to move a point or tool so small a distance as the $\frac{1}{100}$ or even $\frac{1}{1000}$ part of an inch. In astronomical instruments, for purposes of

measurement, the $\frac{1}{10000}$ of an inch is not uncommon.* These are readily obtained by the use of the screw. Let there be one cut with ten threads to the inch, and let the head of this be marked with ten equal divisions. One whole turn will move the nut, to which we may suppose a pointer attached, $\frac{1}{10}$ of an inch; and if the screw itself is turned only one division of its head, instead of one

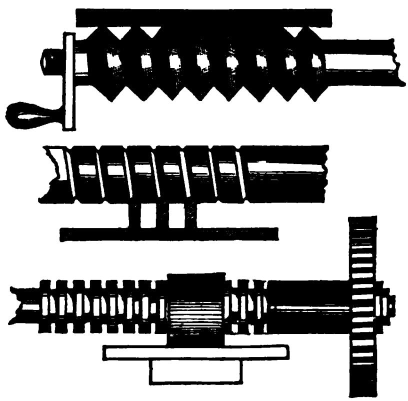

Fig. 33.—Screw-gearing. Nuts, &c.

complete turn, the movement will be only $\frac{1}{100}$ of an inch. A movement of half a division will result in an advance of $\frac{1}{1000}$; and by combining screws, by means of change wheels, so that a whole turn of one shall cause another to move $\frac{1}{10}$ or $\frac{1}{100}$, still more minute subdivisions may be

* In Sir Joseph Whitworth's workshop 1,000,000th of an inch is measured by means of the screw.

measured. Whenever, in short, we require a slow equal movement in a certain direction, whether for parts of machines or for measuring distances, the screw generally supplies the need more readily and with greater accuracy than any other contrivance. It is, however, exceedingly difficult to make a screw perfectly alike from end to end, especially if of slow pitch, or with many threads in a given length.

There is only one other recognised mechanical power which it is necessary to speak of before going into details of actual machines, viz., the pulley. Here again we shall find what all nations seek after, and seek too often in vain, a perfect balance of power. A pulley consists of a sheave or round wheel grooved on its edge, and turning on an axle, which is generally fixed in a block, but may of course be otherwise placed. Pulleys serve first of all to change the direction of power, and secondly to increase it. In fig. 34, A is a simple pulley, which is being used for the first purpose. The power is applied to the weight, through the flexible cord, and its direction is required to be perpendicularly upwards. But the human body is so constituted that it is easier to raise a weight by a downward than an upward pull, because the weight of the body itself can in the latter case be brought into action. We therefore pass the weight over a pulley, and draw the cord downwards. Here is no gain of power, but in some

degree a loss, because of the friction of the rope, and of the sheave of the pulley upon its axle. Theoretically, as before, disregarding the question of friction, a power of 1 lb. applied in any direction will raise the weight of 1 lb. But we can, nevertheless, so arrange pulleys as to make a power of 1 lb. equal to the raising of a weight

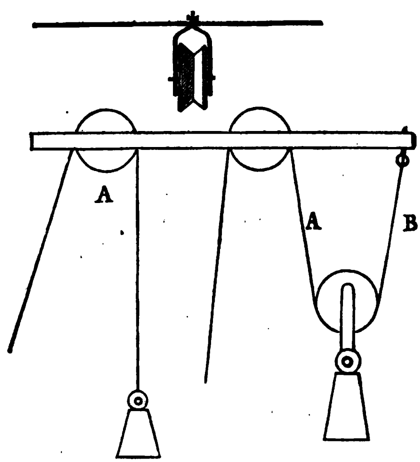

Fig. 34.—Pulley.

of 100 lb. or 500 lb. It will be observed in the first case, in which the pulley is only used to change the direction of a force, all parts of the cord are equally strained, and the weight or power is equally distributed throughout its length.

In fig. 34 we have two pulleys, one fixed and the other loose, and the weight of 10 lb. hangs from the

latter. Inspection of the drawing will show that as the cord is of equal tension throughout each part, A and B bear equally the burden that hangs between them, consequently each bears 5 lb.; but the second part of the cord goes on over the fixed pulley to the hand, which therefore only has to pull with a power of 5 lb. to hold up the weight. Thus the arrangement evidently doubles the power. Theoretically there is no limit to our multiplication of pulleys, but in practice it is not usual to make a combination of more than eight or ten, and even this is not of frequent occurrence.

As we balanced our accounts neatly in treating of the other powers, and took from them the honour of creating force, which they appear to do and do not—like too many human hypocrites—we will see now what is the real full and actual value of a set of pulleys in regard to the work which they are capable of performing.

Take first the combination of two, one fast and the other loose, as in fig. 34. We wish to raise the 10-lb. weight a distance of 6 feet; we therefore lay hold of the cord, and pull. We pull down 2 feet "at a go," as you boys would say, and rest a couple of seconds for a fresh hold and a fresh pull, and down come 2 feet more of cord, and of course the weight has risen 4 feet. Not a bit of it! it has just risen 2 feet, and no more, and we have to pull down no less than 12 feet of cord to

raise it the desired height. Let us see why this is so. When we pull down 1 foot, we shorten by that much the loop in which the loose pulley hangs. Therefore we shorten each half of the loop only 6 inches, and the weight rises thus far, just half the length of cord drawn

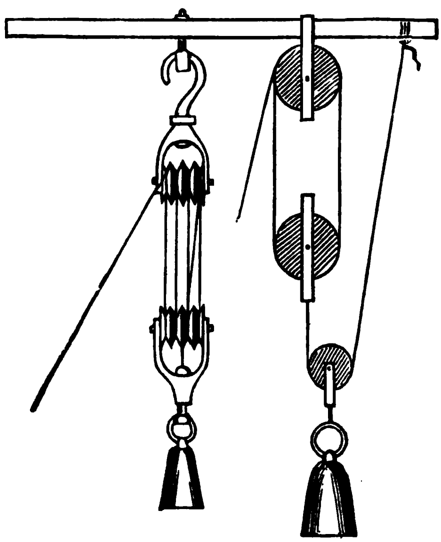

Fig. 35.

out. Again, therefore, observe we use a power of 5 lb. to raise a weight of 10 lb., but we exercise that power through double the distance that the weight is raised. When, as in fig. 35, we add to the number of the pulleys, and by distributing the weight among a greater number

of cords, lessen that carried by each, and consequently that borne by the hand or power applied, we also increase by just so much the length of cord to be pulled down—increase the distance through which the power is exercised just in the proportion that the power itself is increased.

As the pulley rises slowly by pulling out a great deal of cord, so it will sink slowly as it draws out that cord; and by taking advantage of this, we can use the fall of a weight through a short distance to draw out a cord of a great length. This, if wound about a cylinder, gives us the means of making that cylinder revolve many times for each foot that the weight descends, a convenience which our ancestors made use of in working the old-fashioned kitchen jacks. I daresay hardly a dozen, however, now exist in England, but I remember them well.

CHAPTER VIII.

APPLICATION OF MECHANICAL ARRANGEMENTS.

HAVING now laid a sound foundation by explaining the laws which govern mechanical action, I propose in the present chapter to give some details of their practical application in the construction of machinery. We have seen that it is possible by arrangement of cogwheels to obtain at pleasure either quick or slow motion, the former entailing loss of power, and the latter providing for its increase. Levers and pulleys, as we found, follow a similar law; and the first consideration in planning a machine for any particular purpose is the nature and rate of the movement which is required. To take, first of all, a machine of universal application in the construction of mechanism, the lathe, we have a motion originating in an up-and-down movement of the treadle, converted by the cranked axle into a rotary one, and this again communicated with

great increase of speed to the material to be operated on. Now, in the first place we begin with a *loss of power*, for we use a lever of the third order, or of the second order badly arranged, though the arrangement is necessary, because we require speed. There are two kinds of treadle action, therefore, used. The first is A (fig. 36), the knifegrinder's,

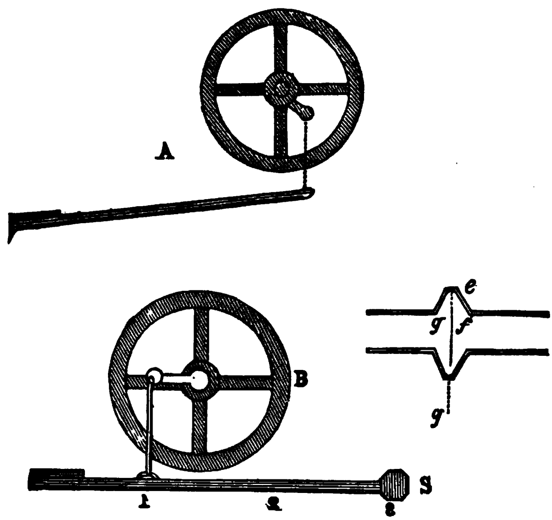

Fig. 36.—Treadle Action.

in which the lever is of the third order. The fulcrum is at the extreme end of the footboard, next to the workman, the resistance at the other extreme, and the power, or foot of the operator, only a short distance from the fulcrum.

If we suppose the treadle 4 feet long, the equation will be as follows, taking the resistance at 40 lb.: 40×4

(the distance in feet from the fulcrum) = 160. The power, supposing the foot placed at a distance of 1 foot from the fulcrum, $160 \times 1 = 160$. It is, in fact, a loss of power in the proportion of four to one. The advantage gained is this. The foot rising and falling a very short distance, moves the other end of the treadle up and down through a much greater distance in the same length of time. We have therefore gained in *speed.* The second form of treadle is shown at B, and is that of the ordinary lathe. The fulcrum is at the furthest point from the foot, the back part of the treadle being pivoted at the end S; the resistance (the crank and flywheel), is at about two-thirds from the fulcrum, the foot one-third on the side of the resistance—*i.e.*, supposing the treadle 3 feet long from the footboard to the hinder bar or fulcrum, the balance of forces may be thus stated, taking 40 lb. resistance as before: R 40×2 (its distance from the fulcrum) = 80; P $26\frac{2}{3} \times 3$ (distance of the power or foot from the fulcrum) = 80.

The resistance, again, is here wholly against the workman; but he gains as before in speed, his foot having only to rise and fall through an arc not very much larger than that through which the resistance moves. Still the loss of power is far less than in the other form of treadle. Here we gain our balance with $26\frac{2}{3}$ lb., and in the first we need 160 lb., the resistance being the same in each case.

But now we have another element of weakness, convenient as it is in its practical application, viz., the crank. This, to begin with, has two dead-points, at which the pressure of the treadle only tends to bend the crank-axle, but not to cause its rotation. These dead-points are obtained by the position *e* and *f* (fig. 36), *g* being the link

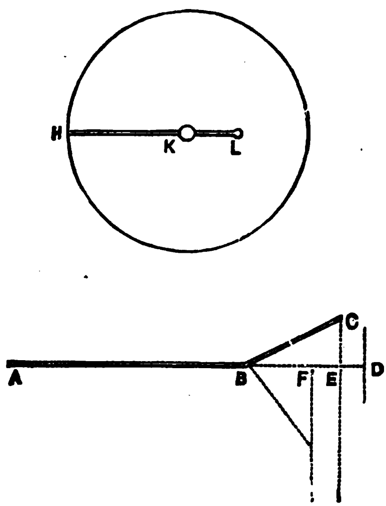

Fig. 37.—Position of Crank.

which connects it with the treadle. At KL (fig. 37) is another view of a crank seen sideways, the flywheel being shown by the circle. In its present position, when the arm is horizontal, which is half-way between the dead-points, it is ready for starting (practically we start it just after it has passed the upper dead-point), and is in its most

effective position, giving us the whole of its power, such as it is. Let us examine it further. The spoke HK and the crank together form a lever, of which the crank is the shortest end and the spoke the longest. Now the resistance falls on the rim of the wheel, or extreme end of the long arm of the lever, the power on the end of the short arm, the fulcrum being the axle. Thus whatever the proportion the spoke bears to the crank, such is the resistance to the power. Let the spoke be 1 foot, the crank 3 inches—a common proportion—then resistance being taken as 40 lb. and expressed by R, and the power expressed by P, we require R 40×12 (inches) $= 480$, P $160 \times 3 = 480$.

We have four to one against us, even when the crank is in its most favourable position, which occurs but once during the whole rotation of the axle and wheel. Thus we lose power both in respect of the treadle and also in respect of the crank. The way to reckon the actual power indeed of the latter, at any given point between its strongest and weakest, is to consider it as a *bent* lever, of which the opposite spoke is the longest end.

Now the effective power of a bent lever ABC is the same only as ABE, BE being shorter than BC; and as BD represents the crank at full power, BE will represent its effective length a certain distance above and BF below that point, and it becomes a shorter and

shorter lever until its dead-point is reached. As it rises on the other side it is of no power at all, and is only carried on past its upper dead-point by the momentum of the fly-wheel. If its full power is represented by 10 when in a horizontal position, it diminishes from 10 to 0 during its quarter revolution downwards, and remains at 0 for another half revolution and a little over. Its power then increases during a quarter revolution, when it is again in full power as before.

Without the heavy flywheel the crank would become almost useless, being only an arrangement for altering direction of motion. I have spoken of the *momentum* of the flywheel in this case as a source of power in the lathe and similar cases. It does not *generate* power, nevertheless, but acts as a savings bank for the deposit of surplus power, which it pretends to give us back with interest when needed. The interest is, however, a fallacy.

When we put any inanimate object in motion, its tendency is to continue that motion indefinitely in the same direction. We call this "vis inertiæ." At first the law seems against experience, because if we set a stone in motion it soon ceases to move, and falls to the earth; and if we set a wheel spinning on its axle—our lathe-wheel, for instance—it ceases to revolve soon after we discontinue the force which set it in motion. But a

moment's consideration shows us that inert matter has no power or will of its own, it simply yields to that which we impose upon it, and therefore has no power to *cease* moving, any more than to *commence.* The reason, therefore, that a body set in motion only continues to move for a very short time is that it meets with resistance. The stone is opposed by gravity tending to draw it to the earth, and by the air or atmosphere through which it has to make its way. These very soon bring it to a standstill; the momentum, or tendency to move, first imparted to it being insufficient to enable it to withstand the contrary forces opposed to it. Now when we set in motion a heavy wheel, we give it this so-called *momentum*, and as the motion becomes more rapid this momentum increases. It is therefore very soon much more than is sufficient to carry the wheel round *once* against the forces which oppose it, and suffices to carry it round a great many times, and to overcome *more* than the obstacles resisting it. Thus, having accumulated more power than is needed (but no more than has been imparted to it), it is ready to give us back its surplus power when needed. Thus it is that it carries the crank past its dead-centres, and gives sufficient impetus to the wood or metal on the lathe to enable it to revolve against the action of the tool. The latter, however, would soon bring it to a standstill were it not that after the

upper dead-point has been passed we again bring down the foot upon the treadle, and keep up the motion. As the flywheel takes up surplus power if there be any, and gives it out again, when otherwise the resistance would stop the machinery, it becomes an equaliser of motion, keeping power and resistance upon an exact balance. This leads me to another beautiful law of matter, which at first appears impossible, but is easily proved to be true.

We will state it thus:—An express train is moving at *a uniform rate* of speed—say forty miles an hour. Such being the case, *power and resistance are exactly equal.* You will say probably, "How can that be? If Puffing Billy were not pulling harder than the resistance, the train would not go on, and therefore the power must be a *little* the greatest to keep it moving." Not so, as long as the power *is* greater than the resistance the rate of motion will keep on increasing; if, on the other hand, it is less, the same rate of motion will constantly diminish. Consequently, if the motion is *uniform*, neither increasing nor diminishing, the train must of necessity continue to move. Now when we hear of a railway accident, you often hear of the carriages being piled up one on the other, or one is even perhaps thrown over the other. Why? Because the whole train (like the flywheel) has been in rapid motion, and has accumulated an enormous

amount of momentum, tending to keep it in motion. Perhaps this would of itself carry the whole train along for more than a mile after the steam has been turned off. Suddenly it meets with a new resistance—say a balk of timber on the line, barring its progress. What is to become of all the moving-force or "momentum"? It must be expended in some way, consequently the hinder carriages, being prohibited from advancing as before, are thrown right over those in front, and the whole train necessarily becomes, as it were, doubled up. When you trip over a stone and fall, the reason is the same,—your body has a certain "momentum," or tendency to move forward; your foot is suddenly prevented from so doing, and down you go, to the detriment of your nose and knees. In the same way, if a rabbit or hare is running fast, and is suddenly killed by a shot, the momentum causes it to make a complete somersault head over heels; or sometimes, if its motion has been very rapid, it will tumble over a second time before the momentum is wholly expended. All this, you see, results from the fact that matter once in motion tends to continue moving, and will do so until resistance has become greater than power. You see, therefore, once more we have balanced our account, as we did in the matter of levers, inclined planes, screws, and pulleys.

To return, then, to our actual machine—the lathe. We

find, first, that resistance is dead against us; and secondly, that if it were not for the momentum of the flywheel we could not even keep up motion, much less turn it to account. But what we require for turning wood, especially soft wood, is great speed, and to obtain this we can afford to sacrifice power, "momentum" being sufficient for our purpose. But when we wish to work on metal we cannot make a similar sacrifice. The material offers greater resistance to the action of the tool, and the latter would become heated, and lose its edge, if the metal were to revolve against it with rapidity. We shall therefore require all the "momentum" which the flywheel can give us, and in addition, as much additional power as we can arrange to procure.

We have already seen that to increase power we must sacrifice speed, which is exactly what we can in this case afford to do, and there are two ways of accomplishing it. First, we can increase the leverage of the crank by diminishing the length of the other arm, viz., the spoke. This is practically carried out by mounting a smaller wheel on the axle of the large one, so that while we get the full momentum of the latter, we cease to use it at such disadvantage. We have the wheel A (fig. 38) as before, and B is the small pulley from which the cord passes to that above. The radius of this pulley equals here that of the crank; not that it generally does so in practice, but we

may suppose such to be the case. The leverage, therefore, here is at once vastly improved, and, for the moment that the crank is at full power, the latter is equal to the resistance. If the small pulley of the lathe is as large as this lower one, this amount of power will of course be transferred to it by the cord; and if the pulley is 6 inches diameter, and the iron to be turned is only 1 inch, we attack the latter with a power of six to one. By enlarging our upper pulley and lessening the lower one, we can yet increase this power and make the work easier; but here comes the balancing of our account again, *we keep on diminishing the speed exactly in the proportion that we increase the power*. This is the first and simplest way of attaining our purpose. The second, and practically the best, is as follows:—

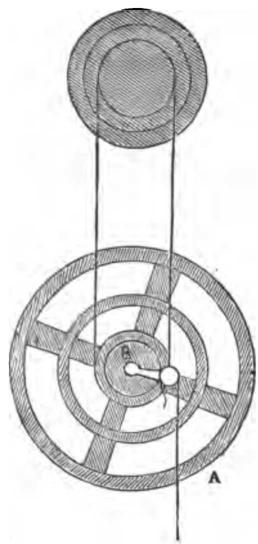

Fig. 38.—Lathe Speed-Wheel.

Fig. 39 shows the upper pulley of what is called a geared or back-geared lathe. It has a small cog-wheel or pinion attached, which therefore always moves with it; but both pulley and pinion slip on the mandrel A, and turn freely upon it, not being keyed or otherwise fixed to it, as in

simple lathes. The mandrel, however, has a large cog-wheel firmly fixed to it, as seen at A, where I have shown it separately. First I may premise that it is possible to clamp the pulley and this large wheel together when desired by a small bolt and nut, and then, supposing the other cog-wheels which you see behind it to be out of the way, the pulley and mandrel will turn together as in lathes fitted only for wood. The cogged wheels do not in this case come into action at all. But if we require more power, we unfasten the bolt and nut, and thus leave the mandrel and its own large cog-wheel free to revolve independently of the pulley and pinion. We now slide the back action into gear, which is generally done by moving it endwise in its bearing.

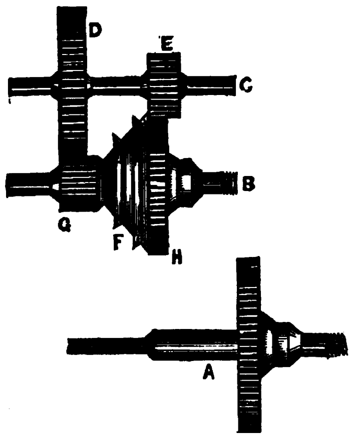

Fig. 39.—Geared Lathe.

Now observe the action of the whole. The lathe-cord from the flywheel rotates the pulley, whose pinion sets in motion the large wheel of the back action. The pinion of this acts upon the large wheel on the mandrel, and puts this in motion, and with it the metal which is to

be turned. The power gained, supposing both spur-wheels alike, and also both the pinions, is equal to twice the difference in size or number of cogs between either wheel and pinion. Let the spur-wheels have sixty teeth and the pinions ten. While the pinion on the pulley moves round upon its axis once, D will move but one-sixth of its circumference, and its pinion, therefore, also but one-sixth, equal to one cog and two-thirds of a cog; and the movement of the large wheel on the mandrel, and therefore of the work, will be but one thirty-sixth of its circumference—less than two teeth. Or, to make it plainer, six turns of G will give one of D, one therefore of its pinion E, and only one-sixth (= ten teeth) of H and of the mandrel. It will take, consequently, no less than thirty-six turns of the first pinion to give one turn to the large wheel and mandrel, and the gain, being proportionate, is thirty-six to one. Thus, in cases where speed is no object, and power only is required, the latter can be, and generally *is* obtained through the medium of geared spur-wheels and pinions in this way.*

All machines, almost without exception, for working metal require this slow motion, whether used for turning, or planing, or grooving. Drills, indeed, are often driven

* The above may be stated thus :—

$$\frac{\text{Number of teeth in pinions}}{\text{Number of teeth in spur-wheels}} = \frac{10 \times 10}{60 \times 60} = \frac{100}{3600} = \frac{1}{36} \left.\right\} \text{loss of speed or gain in power.}$$

at a somewhat high speed, but the area of their work is very limited, and the resistance consequently small. They are, moreover, kept well lubricated and cool by water or oil, to prevent them losing their temper. As a rule, if we go to an engine-factory, and notice any machine moving at what appears to you a specially slow rate, appearing to be doing hardly any work, you may rest assured that is some immensely-powerful machine working a great deal harder than those which you see spinning so merrily, and making so much more noise. In this I think machines and boys are much alike—ay, and men too. Some go plodding quietly along, doing their work very silently—doing a hundred noble things which no one ever sees except those benefited—and even these do not always recognise the benefactor. The others go along noisily and showily, saying to the world, "Only see what a deal of work I am doing; what an excellent fellow I am!"—but the one eventually becomes recognised as a benefactor of his race, and is honoured of all men—the other fades from sight like the gaudy butterfly, and none ever miss him, because his real work was simply nothing.

CHAPTER IX.

OTHER MECHANICAL EXPEDIENTS.

WHEN, as is generally the case, a great number of machines are to be set in motion by a single steam-engine, a strap from the flywheel of the latter passes to a pulley or "rigger" upon a long shaft, traversing perhaps the whole length of the workshop. Upon the shaft are other riggers, from which straps descend to the main axles of the several machines. These riggers are in pairs—one fixed to the shaft, the other revolving loosely upon it. One is called the fixed pulley, the other the loose or "idle" one, and when any particular machine is required to be stopped, its strap is merely slipped from the fast to the loose pulley. Thus the stoppage of any one of a set of machines does not interfere with the rest, and the main shaft continues to revolve as before. The great advantage of strap action is that under any sudden and unusual strain the strap will slip

and save the machine from injury, and, in addition, by this plan of fast and loose pulleys motion can be recommenced without any shock to the apparatus, at whatever rate the main shaft may be moving. All sorts of "clutches," as they are called, have been invented to enable the action of a machine to be suspended and renewed while the main shaft which imparts motion continues its rotation, but none is so safe as this simple arrangement of fast and loose pulleys. The difficulty of suddenly stopping or starting a machine arises from "the law of momentum" of which I have spoken. Suddenly to throw a machine into gear while the prime mover is in rapid motion is like running an engine full tilt against a stationary truck, in which case you would probably smash it, although it is perfectly free to move. You do not give the momentum of the engine time to become imparted to the truck, and time alone can save the shock in such a case. This is indeed an instance of motion in a straight line, but it explains equally well circular motion, which likewise cannot be *suddenly* imparted to a stationary object or a still wheel, but requires time. A strap exactly answers this end, because it is quietly slipped from the loose to the fast pulley, and if the resistance is too sudden, it will slip a little, or stretch slightly, from its elastic nature.

I may as well mention here that some manufacturers are taking up the practice of using several small engines

connected with one boiler, so that perhaps only three or four machines are driven together as a group. Then if there should be an accident to any one of these engines, only a single group of machines are brought to a standstill; whereas, if one large engine drives the whole series, a breakdown, or a necessary cleaning of the prime mover, necessitates the stoppage of all the machines upon the premises. It is evident that as the engine imparts only a rotary movement to the main shafting, and thence to the various machines, the latter have to be fitted with appliances of some sort by which this rotary motion may be converted into other movements of various kinds. The present chapter will be devoted to a description of the methods that have been devised for this purpose, and *vice versâ* for the purpose of converting rectilineal motion into rotary. Some of these methods are exceedingly ingenious, and all, or nearly all, are in daily practical use. To make the movements clear, I propose to group them, and shall explain each group individually.

Let us first see how we can convert circular or rotary motion into rectilinear. The planing-machine will illustrate one usual method, or the shaping-machine, which is a smaller one of the same class. In these either the bed is moved to and fro while the tool remains stationary, or the tool itself traverses and the material to be planed is clamped upon a level platform or bed underneath it. Let L (fig. 40)

represent the pulley or rigger by which motion is imparted to the machine from the main shafting. On the opposite end of the same axle is a crank-plate or solid circular wheel, with a deep slot or groove cut across its face. In this is a slide, with a strong pin rising from its centre, and the slide can be clamped in any desired part of the main plate. The arm A has an eye which fits over the

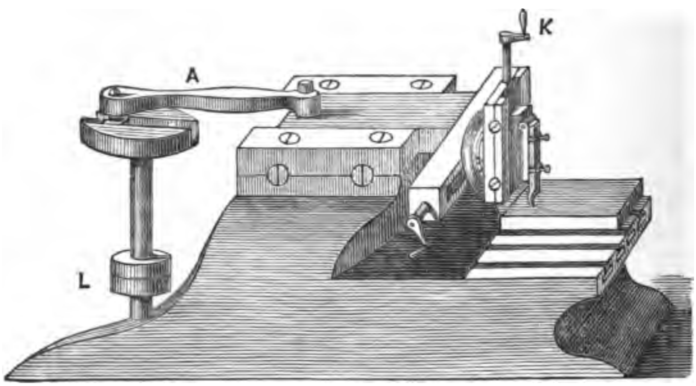

Fig. 40.—Shaping-Machine.

pin, and at the other end is attached in a similar manner to the main slide of the engine, which carries the tool-holder. This slide has only a to-and-fro motion between guides, and therefore, as the rotation of the crank-plate acts on one end of the bar or connecting-rod A, the other end draws the tool-slide backwards and forwards. The length of stroke varies according as the driving-pin is nearer to or further from the centre of the crank-plate,

its longest stroke being of course when the pin is at the extreme edge of the disc, and its shortest when almost at the centre or axis of rotation. The handle K is for the purpose of raising and lowering the tool in the slide-rest, to which it is attached, and there is a movement also of tool or work sideways between every stroke, so that eventually the whole of the latter becomes levelled by the action of the tool. Details of these motions are omitted here. These crank-plates, being simple and convenient arrangements for converting circular into reciprocating movement, are very frequently used for that purpose, but there are several other modes of obtaining a similar result. It will be seen that an ordinary crank, as, for instance, that of a lathe, which, when the flywheel is moved, lifts and lowers the treadle alternately, is exactly the same thing in principle as the one here alluded to, but not being adjustable in length, is not so convenient for shaping-machines, in which it is often necessary to alter the distance of traverse of the tool.

Closely allied to the crank is the eccentric (fig. 41), which gives a very beautiful to-and-fro motion, and is generally used to move the slide-valves of engines, and for many other purposes. On the main or other revolving axle of the machine is a thick metal disc or solid wheel; but this is not concentric with the axle, which passes through it at any given distance from its real centre. When, there-

fore, the axle revolves, this disc revolves with it; but while one point in its circumference describes a large circle, another will describe a smaller round its axis of rotation, so that, to use a common expression, it appears to wobble.

A ring of metal embraces the edge of this disc, fitting it nicely, but so that the disc can move easily inside it, and to this ring a long rod or light framework (which acts as a simple rod) is attached, and its end is connected to that part of the engine or machine in which a recipro-

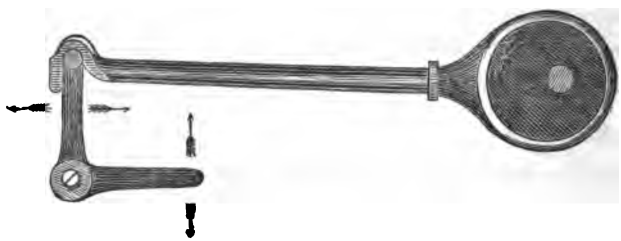

Fig. 41.—Eccentric.

cating motion is required, being pinned or jointed to it in such a way that the connection forms a hinge. Very frequently the end is formed into a hook, which drops over a pin in the plate to which sliding motion is to be imparted. An eccentric is nothing more than a solid crank, its "throw" being twice the distance between the real centre and that on which it revolves. It is generally used where only a short stroke is required, and gentle, easy motion, and where an exceedingly short-armed crank could not so readily be applied. The motion of a crank

or eccentric is not uniform, being quick at two opposite points and slow at two other points halfway between them. The rate of motion is consequently always becoming accelerated or retarded between these points. An eccentric is sometimes used as a "cam," without its encircling ring, as in fig. 42. Here it gradually raises and lowers the arm of the lever connected with it, which may represent one handle of a pair of fixed shears. "Cams" are of all possible shapes, and are used in

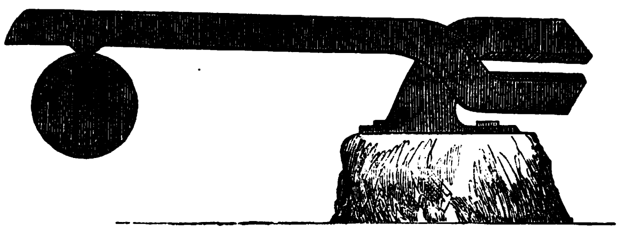

Fig. 42.—Eccentric Cam and Shears.

machines of various kinds, as they can be arranged to produce uniform or varied motion, and provide means for the application of enormous power. In the construction, for instance, of the massive punching and shearing machines used for cutting boiler-plate and preparing it for the rivets, cams are used, in connection with a train of wheels, to produce very slow and powerful motion. The working part of this machine is shown in fig. 43. The flywheel K, of which there are often two with very heavy rims, is put in motion by means of a strap from the engine

attached to its rigger F; or frequently a separate engine belongs to the machine, and cog-wheels only are used to work it. On the main shaft is a very strong pinion gearing into a spur-wheel, which again carries a second

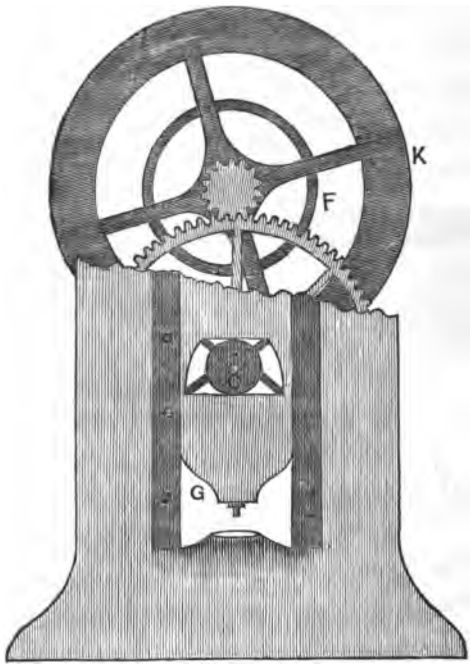

Fig. 43.—Punching-Machine.

pinion, and gears into a spur-wheel with a massive axle on which is the cam C—an eccentric boss, in one piece with the axle. Here I have, for the sake of clearness, shown but one pinion and spur-wheel, which will answer

if a vast amount of powei is not required. As the main shaft with the flywheels revolves with a fair amount of speed, giving the necessary "momentum," the lower shaft and cam revolve very slowly, owing to the great difference in size between the pinion and spur-wheel, as in the geared lathe already described. Slowly, therefore, and in large machines with irresistible force, the head of the sliding part G, which carries the punch or cutting edge, is depressed by the eccentric cam, and the metal is sheared or punched as if it were cheese rind. The shape of the cam is such that it commences to give a quick descent to the slide, but gradually diminishes its speed while increasing its power.

I know of no machine which strikes the looker-on with a greater sense of the power produced by machinery than these massive machines, which are now so generally used. Sheets and bars of iron, nearly or quite an inch thick, are bitten in two by these huge jaws as (apparently) easily as you could cut a piece of card with a pair of scissors. If, however, you pick up a piece *punched* out, you will see by the depression on one end, and also find by the heat of it, what vast force has really been exercised upon it. Of course the frames of these machines are very massive, and all parts as strongly made as possible.

Another common application of eccentric-cam action is to cause the necessary pressure for printing and for the

stamping paper or envelopes with crests or addresses (fig. 44), and indeed for supplying pressure in various cases, where a quick, powerful action is needed, and it would take too long to obtain it by the rotation of a screw.

Our *subject*, however, is not cam action or eccentric action generally, but only the method of producing

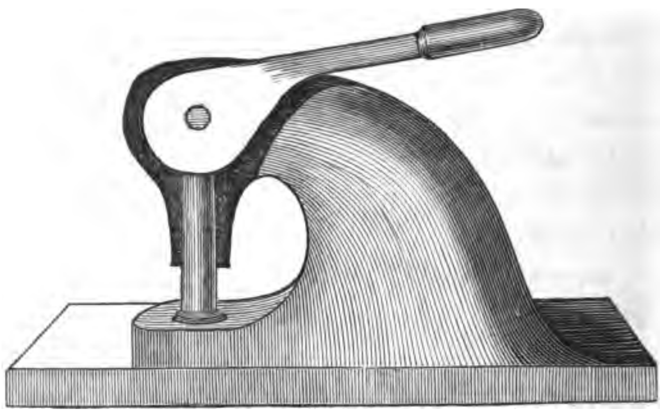

Fig. 44.—Section of Die-Press.

rectilineal motion by means of rotary, of which these powerful actions are common examples. Sometimes the up-and-down or horizontal movement of a slide is not required to be continuous but intermittent—to begin, cease, and recommence either in the same or contrary direction; and this, at first sight, complicated movement is to be derived from a primary rotary motion of the

main shaft of the machine. There are many different ways of accomplishing this. First of all, a wheel with only a few cogs may be made to act alternately on an upper and lower rack, attached to the end or other part of the bar to which it is necessary to impart the intermittent motion alluded to, as shown at A, fig. 45. The wheel continues to revolve in one direction, but necessarily moves the rack to and fro. B is another method of producing

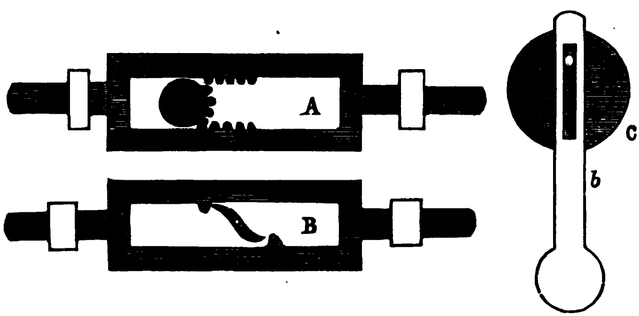

Fig. 45.—A, B, and C.

similar motion, in which, instead of cogs and racks, a set of tappets or wipers are made to act against a single pin or tooth in the two bars. In the case of the slit or slotted lever *b*, moved by a pin in the face of the revolving wheel A (the lever vibrating on a centre pin), a varying intermittent motion is produced.

We will now reverse the case and see how rectilinear motion can be converted into circular. First, we have our friend the crank and treadle, which has been

described, and is, moreover, generally known and used. But when Watt in his steam-engine desired to use it, in order to convert the up-and-down motion of the end of the beam into a revolving motion of the crank axle, he

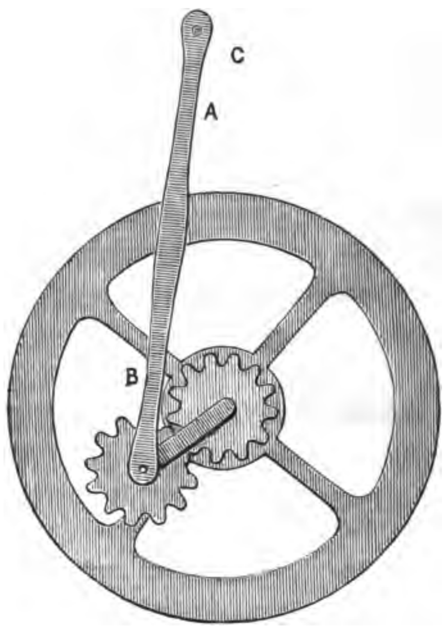

Fig. 46.—Sun and Planet Wheels.

was prevented by some one else claiming the discovery. He therefore arranged two cog-wheels, which, owing to their movement round one another, went by the name of "sun and planet wheels" (fig. 46). One of the cog-

wheels is fixed to the axis of the flywheel, the other to the rod AB, which oscillates on the point C as the beam end goes up and down. The wheel, be it observed, does not turn on a centre of its own, being immovably fixed to AB. A link keeps the two wheels in contact, and this link is free to move on its centres. As therefore AB oscillates to and fro at each movement of the engine beam, the wheel attached to it revolves round

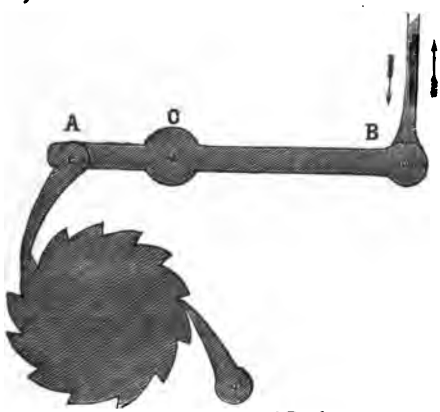

Fig. 47.—Ratchet and Pawl.

that one on the axis, and puts the flywheel in motion; and if the two wheels are of one size, the flywheel will revolve twice, while a common crank would have given it but one rotation on its axis. This method, not being so simple as the crank, has fallen into disuse, and was never very generally adopted. The ratchet and pawl (fig. 47) have been used in various machines—notably in the

planing-machines for metal, and in sawing-machines. They were used also by Bain and others in his electric clock, and form a very simple but ingenious mode of converting rectilineal into circular motion.

The lever AB is pivoted at C, and can be moved up and down like a pump-handle. As the end A rises, the pawl, which is loosely hinged, slips over the sloping side of the wheel-tooth; but as the lever descends, it falls on the other side of the tooth, which it is compelled to push onwards, giving the required motion. Sometimes there are two pawls, as in fig. 47, so that one tooth is moved both at the upward and at the downward motion of the lever, and the wheel revolves continuously instead of intermittently.

The Archimedean drill-stock, and the pump-drill, used generally by menders of china and glass, and the drill-bow of the watchmaker (fig. 48, A, B, C) are all examples of a to-and-fro or rectilineal movement being used to obtain a circular one. The pump-drill consists of a flywheel with a heavy rim, round the axle of which two cords are twisted, being also fastened to the top of the axle. The latter is vertical or upright, and is bored out at the lower end to receive the drills. A cross handle, through the middle of which the axle passes, has one of the cords fastened to each of its ends, and it is the sudden pressure on this handle,

after the cords have been coiled once or twice about the axle, that causes the drill to spin round with rapidity. In so doing the momentum of the flywheel keeps up the action, and twists the cords in the opposite direction, thereby shortening them and raising the cross handle—

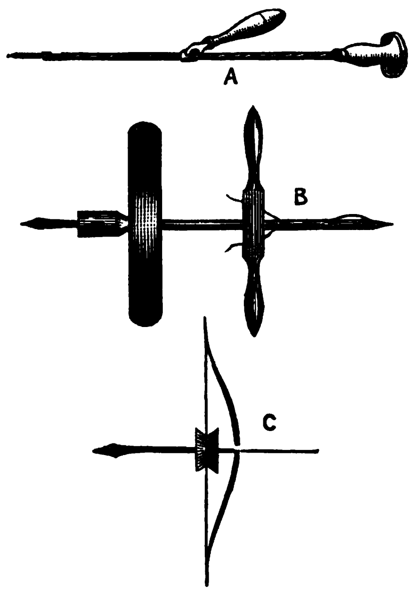

Fig. 48.—Drills.

the pressure of the hands being withdrawn to allow it to rise. The handle is then pushed down again, the cords unwind, and fresh impetus is given to the drill, the motion of which is continuous in one direction. The other two

drills owe their action to a different cause. The stock or shaft has a quick screw cut upon it, and on this is fitted a nut. By pulling the latter up and down upon the screw, this is caused to make a few quick turns, first in one direction and then in the other. These twisted drills are beautifully adapted for small work, and are extensively used, but the bow-drill is by no means gone out of use in the watch trade. This same bow is used also by the watchmaker to give motion to small wheels and pinions which are to be turned in his miniature lathe. This is done by taking one turn of the bow-string (gut or horsehair) round a small brass pulley fixed upon the drill-shaft, or upon the work to be turned, and pulling the bow to and fro by the left hand, while the tool is held in the right (see fig. 49). Of course the cut can only be taken while the work revolves against the tool, and therefore time is wholly lost while it revolves in the contrary direction. It may seem wonderful that good accurate work should be done

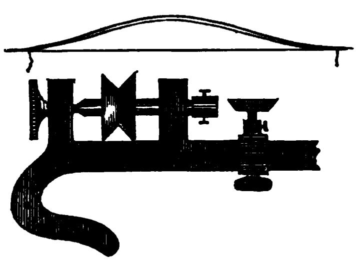

Fig. 49.—Bow-Lathe.

by such means, but even now, not only is the bow-lathe used generally for watch-work, but the spring pole of the large lathe, fixed up above the head of the turner

from which a cord descends to the treadle, may still be seen in the shops of some soft-wood turners and chairmakers. The action is just the same as that of the bow. The cord of raw hide descends from the pole, takes a turn or two round the piece of wood to be turned, which rotates between two fixed points, and passes to the treadle, where it is fastened. When the foot presses downward, the wood revolves against the tool; and when the foot is raised, the spring pole or bow draws up the treadle, and rotates the work in the opposite direction.

CHAPTER X.

VARIOUS MANUFACTURES—STEEL PENS.

I HAVE already explained the form of stamping-press used for embossing notepaper, and for similar light purposes. When, however, great and sudden power is needed, the screw made with a quick thread—*i.e.*, with one complete thread in 2 inches or so of its length—is used instead. One turn of a screw of this pitch will cause a die to descend 2 inches with great rapidity. Such a stamping-press is shown in fig. 50, and the heavy balls on the lever supply the place of a flywheel with heavy rim, and give the necessary impetus or momentum. As already explained, this arrangement of "fly-press," as it is called, is used in the Royal Mint for punching the coins from flat strips

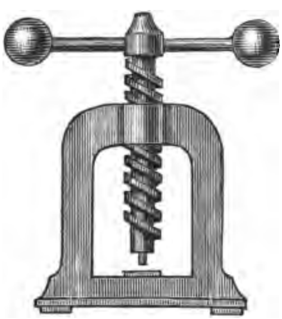

Fig. 50.—Stamping-Press

of gold and silver, for hand-presses for printing and copying letters, and for many processes in our manufactures—one of the most notable being the punching from flat ribbons of steel the pens of which so many thousands are now used, and also for bending them into the various forms which are usually given to them. The present chapter will be devoted to an account of steel-pen making, as witnessed by the writer on a recent visit to the manufactory. We will sketch the trip as we scribbled it down at the time, and it is just such a one as we should wish our boys to take.

A VISIT TO BIRMINGHAM IN 1872.

In the early spring of the above year, we found ourselves beneath the magnificent glass roof of the Birmingham New Street Station, into which we had emerged, with a shriek of recognition, from the bowels of the earth—our somewhat tedious and monotonous journey having ended with a rush through a tunnel. Almost before the pantings and snortings of our iron horse had died away, we had seized our limited assortment of traps, and were on our way; for be it noted, for the edification of travelling readers, that our traps, or duds, or baggage, or lumber, are always on an exceedingly limited scale when we migrate apart from the wife of our bosom and certain innumerable pledges of her affection, which always

suggest to us "unlimited liability." Our boys will of course understand that we refer to the girls and the babies. The bassinette and perambulator, and trunks and baskets for dresses, they will appreciate as literally "impedimenta" on such journeys as the present. A drive to the quarters assigned to us in the hospitable mansion of an old friend suggested very decidedly *smoke.* Smoke above, denying a glimpse of the outer walls of heaven—smoke below, in sooty griminess trodden into black mud—smoke on all sides, giving effects of cloud-land and distance, in which Turner would have rejoiced—but smoke that was ever repeating the dictum of the alchemist, that baser metals could be turned into gold. Under that dark canopy, day by day and hour by hour, patient workers were toiling with that unremitting labour of head, of hand, which helps forward not only the wealth of nations, but their civilisation.

> "Labour for the chapman at his trade, a dull unvaried round,
> Year after year unto death; yea! what a weariness is it!
> Labour for the pale-faced scribe drudging at his hated desk,
> Who bartereth for needful pittance the untold gold of health.
> Labour with fear, for the merchant, whose hopes are ventured on the sea;
> Labour with care, for the man of law, responsible in his gains;
> Labour with envy and annoyance, where strangers will thee wealth;
> Labour with indolence and gloom, where wealth falleth from a father;
> Labour unto all—whether aching thews, or aching head, or spirit."
>
> M. TUPPER.

Soon, however, we found that we had left the smoke, emblem of darkness, behind, and that either the cloud had cleared away, or we had reached the silver lining; and a sudden turn in the road introduced us to a clear atmosphere, goodly houses, pleasant fields, and fair churches; another turn, and we were safely housed, and, what is even far more to be prized, warmly welcomed. Thus auspiciously began our introduction to the sights of Birmingham, and what we saw, and what we did, and what we thought will occupy the following pages.

As the pen is our weapon of offence and defence, our cherished friend and our general messenger, we thought it best to commence our tour of investigation by visiting its birthplace, and an introduction to Gillot & Co. quickly procured us the desired permission. This manufactory is always open to inquiring visitors, and this is not one of the *sealed* manufactories which are daily becoming more numerous. There is a visitors' book on which autographs of all nations may be studied, and in which henceforth our own caligraphy may be inspected and admired.

The steel used for pens is rolled into thin plates before it reaches the Birmingham factory. It is, however, rolled again at the latter place to the exact gauge required, and is given into the hands of the blank-cutters as narrow slips wide enough to allow of two pens being cut therefrom end to end, as shown by D in fig. 51. The flat blank of

an ordinary pen appears as A, that of a small barrel pen as B, and the larger or *magnum bonum* as C. There are

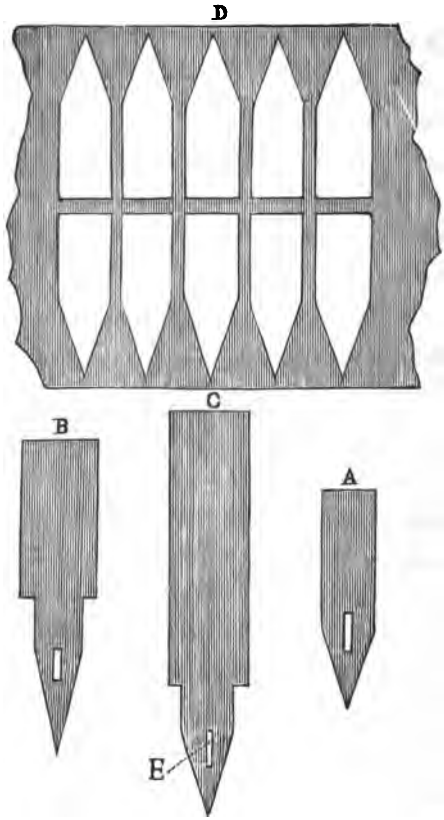

Fig. 51.

other forms used by different makers, and also by the Messrs. Gillot, but the above, which are the most common,

will suffice to give a clear notion of the various processes required. All these are cut at fly-presses by women, who are very largely employed in this work. The machines required are made and repaired upon the premises, which appears to be a very general rule with the Birmingham manufacturers. The waste pieces like D, especially those from which the long barrel pens have been cut, would, if polished, have a highly ornamental appearance, and might, one would have supposed, be used for various purposes of decoration. Such, however, is not the case, and they return eventually to the melting-pot, or are otherwise worked up anew. It must be understood that in this, and indeed in all similar manufactories, division of labour is carried out to the utmost. Each workman is tied to a single operation, which he (or she, as the case may be) constantly practises from day to day, and in which therefore rapidity and neatness of execution are quickly attained, and, in many instances, the special work originally learned is the only one that is understood. After the flat blanks have been punched out as above, they pass to another set of presses, in which the hole E, for the retention of the ink, and the two small slits are made, for the purpose of giving greater elasticity to the pen. The size, shape, and position of these are varied according to the pattern of pen required, but in all cases the punching operation is the same.

The next operation is stamping upon the blank the maker's name, with the number or letter by which the particular kind of pen is to be recognised. As rolling and stamping deprive the steel to some extent of its flexibility, the blanks are now sent to the annealer, who softens them by the application of heat, rendering them fit to undergo the process of bending to the required form. This is done as before by a set of punches, the common pen being placed on a simple hollow die, and struck by a convex one. The barrel pens are similarly begun, and finished between a pair of concave dies. It will be readily perceived that these dies regulate both the curve and figure of the pens, the variety of forms issued by penmakers with different high-sounding names being each supposed to impart some special quality to the instrument. For our own part we believe in two qualities only, elasticity and breadth of point, and as to the latter we commonly grind it down to suit ourselves; but when we have done, and made our pen somewhat like an elastic stick, we are still fain to confess there is nothing equal to a good quill, albeit it is difficult to procure.

The present volume certainly would never see the light of day, if the writer were compelled to resort to steel pens for the necessary preparation of MS. At the same time, it must have been a grand day of rejoicing among the Lincolnshire geese when the first steel pen was an accom-

plished fact; for it is also a fact, and to the geese a painful one, that the quills were ordinarily plucked from the living bird, who was then turned loose to grow a fresh crop the following year. This, I suppose, was a necessary barbarity, as it would hardly have paid to kill a goose for the dozen pens that the wings afforded, any more than it paid to kill another fabled goose which laid golden eggs.

After the various fly-presses have done their work, the pens are finished upon a grinding-wheel dressed with emery, upon which also the points are carefully finished. The blanks may now be considered to have assumed the features of steel pens, but are not slit. This, again, is a stamping operation, and is effected by two sharp punches, which meet like the edges of a pair of scissors—one being fixed in the bed, and the other in the facing part of the press. The metal now needs to be tempered, which is effected by heating a number together in a muffle, or close iron vessel, in a furnace, and throwing them, when of a dull red, into oil. The sudden cooling renders the pens so hard that they would break to pieces instantly under a blow, and they have in this state no elasticity whatever. They are raised on a kind of colander from this oil-bath, and placed in a revolving cage over a number of gas-jets, where, as the heat gradually increases, they assume various colours, beginning with the palest straw, and passing through deeper yellow, orange, purple, and blue. The latter is

spring temper, which must not be exceeded. The pens are now practically finished, but are often coated with varnish, which, when dry, gives them a smarter appearance.

Such is briefly the process of steel-pen making; but there are one or two additional softenings or annealings of the steel as an intermediate operation, and certain scourings in revolving vessels, in which they are shaken about with pounded gritty material until they are rendered bright, and their rough edges, caused by grinding and stamping, rounded off. Now that steel pens are every-day affairs, we think little of the process of manufacture; but the amount of thought and capital expended on the necessary machinery, simple as it may now appear, was very great, and does great credit to the enterprising firm of Gillott & Sons of Birmingham, who originated and personally made the greater part of it.

Having the pen at hand, we require a suitable holder, and (except for barrel pens) this article consists of a well-formed, and frequently ornamented, stick of cedar or other wood, with a metal addition for the actual reception of the pen. The latter part is made, like the pen itself, by means of stamping-presses, which first cut out and then roll up the metal into a tubular form. For this work sheet brass and other metals are used as well as steel. The wooden sticks are made wholly by machinery, and a large quantity of timber is cut up yearly for their production. First of

all the wood is cut into boards of a suitable thickness, and these boards are passed into a machine which is practically a plane with semicircular notches cut in the iron. The board, being placed first on one side, appears thus (fig. 52). It is then reversed, and similarly worked on the opposite side, when the long rounded strips are separated. These are long enough for several penholders, and are cut rapidly into lengths by a circular saw, there being a gauge to regulate the sizes required. These are now placed in a machine in which each stick is made to pass between figured dies, which not only impress upon them the desired pattern, but also by simple compression diminish slightly that part upon which the tube of metal is to be placed. So perfect is the operation of this machine, that it rejects automatically any damaged sticks, throwing them out of one part, while the finished holders fall from another into a box placed for their reception. If the handles are to be tapered, the dies which form them are made gradually to close as the stick passes through them. All that is required is to feed the machine with its allotted number of sticks, and these are digested and finished in form and figure with a rapidity and certainty astonishing to the looker-on. Yet to those practically acquainted with the

Fig. 52.
Penholders.

powers of machinery, and the possibility of so adapting the different parts of machines as to render them capable of the most complicated and varying motions, no work of the kind seems impossible. The precision with which these pen-making machines, however, work, is, to say the least, equal to clockwork, and the wear and tear they have to undergo necessitates excellence in material and fitting of the very highest degree.

Before the public receive the steel pens they require to be packed in boxes, which are nevertheless charged at so low a price that no practical difference is made on the cost for 100 pens loose or 100 thus securely packed. The box-making is both simple and ingenious in its details, and the *modus operandi* is as follows: The fly-press at a single blow cuts out the thin cardboard into pieces of the shape shown at A, fig. 53. Where the folds are to take place the card is also partially cut, that it may bend easily and form sharper edges.

Women, who are very generally employed in pen-making, sit at a long bench, on which lie paste and scissors, paper of various colours, and little wooden blocks, of certain sizes, which are the moulds on which the pen-boxes are made. One of these is shown at B, and it will be seen that it has a horizontal groove cut round it about the middle, but a little higher than the exact central line. The blank of card is laid on the table, and one of the blocks

which fits it laid inside. A similar blank is laid upon the top, and the edges of the two exactly meet, as here shown, the junction being just over the groove cut in the block. A slip of coloured paper is rapidly folded round, and another piece laid upon the top with a speed and dexterity only to be attained by constant practice. The box and cover are thus made as one (C), and when dry a sharp knife is passed round on the line of the groove. The top and

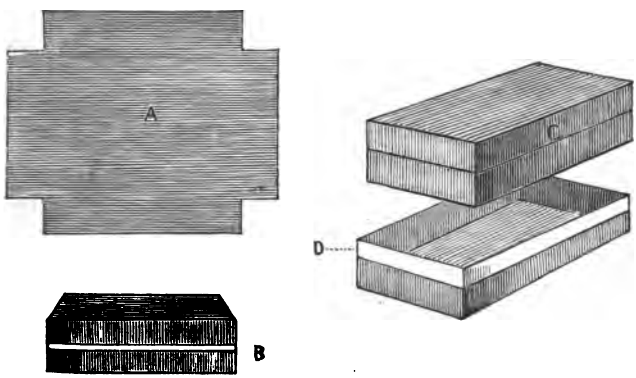

Fig. 53.—Pen-Boxes.

bottom are thus separated, and the block falls out. It is, however, necessary that the cover should slide over what a carpenter would call a rabbet (rebate), D, as it could not be made to keep its place. A strip of cardboard already cut, and folded over a similar block to ensure an exact fit, is therefore pasted inside the box so as to stand up a quarter of an inch above its edge, thus forming a guide and

resting-place for the cover. The whole operation is carried on a great deal more quickly than it could be described even by the most rapid pen; but it must not be supposed that one person could complete the whole with the necessary speed to make the work pay. The blanks are stamped by one, passed on in piles to the next, who has these on one side of her and the wooden blocks on the other. Having enclosed the latter as already described, and pasted a slip of paper on, to hold them together (this paper being cut and pasted ready for use by another), the box is passed on to the next, who covers it. Another carries the piles to a warm place to dry, and then another cuts the top and bottom asunder, and places the thin slip inside for the cover. Thus, like the pens, each box goes through a number of hands trained to do their own special part in the manufacture. When the boxes are all complete, the pens are counted and placed in them, secured by a single strip of paper, on which the number and quality are marked. A gross, or twelve dozen, are very commonly in one box; but of the *magnum bonum* and other large pens a dozen only are usually packed.

In the showroom may be seen pens a great deal larger than any commonly used, and also others so small that it is almost impossible to believe they can be pens. Under the microscope, however, they are seen to be perfect and beautifully finished. Of course these are but curiosities.

One thing that especially strikes the visitor to Messrs.

Gillott's factory is the happy and contented appearance of the numerous workers. For all the lighter work women appear to be employed, but for the heavier machinery for rolling the steel and planing the boards which are to be made into penholders men are necessary. The whole range of buildings is well adapted for the work to be carried on. The rooms are large and lofty, well lighted and ventilated, and are kept scrupulously clean, and everything that can promote the physical and moral welfare of the workpeople is adopted. I have spoken of rolling the steel, but the latter is manufactured elsewhere, and the rolling done at the pen manufactory is merely necessary as a finishing process to reduce the ribbon-like strips to the exact gauge required, and put a better finish upon the surface.

I have now done with steel pens, but I strongly advise my young readers to take any chance that may present itself of visiting the manufactory and personally witnessing the various processes. After reading the present brief account, they will be far better prepared for a visit than if they had previously been entirely ignorant of the work. They now know what to expect and what to look for, and minor details, merely hinted at in this brief paper, but which are nevertheless of importance, will be noted; and the whole process from beginning to end will not only be seen as a matter of interest, but will be fully understood, and appreciated as it deserves.

CHAPTER XI.

PINS.

WE shall again come across our coil of iron wire, of which we have described the manufacture in a previous chapter, and we shall find that one purpose for which it is used is the manufacture of screws for the carpenter and joiner, for which purpose it has superseded the forged blanks used in ancestral days. Brass wire, made in a similar manner, is also used for screws, such as we see in the handsomer articles of house furniture—pianos, and so forth. Drawn still smaller, we meet with it in the form of pins, the sizes ranging from 3 inches down to that of minikins half an inch in length, or even less. When we think of the tens of thousands of pins used in the present day, we wonder what people used to do before they were invented. Well, they are, after all, of no very ancient date. Until the middle of the sixteenth century they

were wholly unknown; and bone, wooden, and ivory skewers, or (with rich people) gold and silver ones, with brooches and clasps of divers kinds, were used by ladies for the purposes for which pins have since been substituted. The first pins were introduced, like most novelties, from abroad; but in Henry VIII.'s time a manufacture of pins seems to have had sufficient footing in England to call for an Act of Parliament. This Act required that no person shall put to sale "any pins but such as be double-headed, and have the heads soldered fast to the shank, well smoothed, the shank well shaven, the point well and roundly filed, canted, and sharpened." What these double-headed pins were the writer does not know.

A pin now consists of only one piece of wire pointed and headed. In old days it consisted of two, the head being itself a little coil of wire slipped on the pin, and secured by a blow from a punch. To make these heads a thin wire was coiled round another of the same size as the pin, the coils being quite close together, and afterwards, by means of a pair of shears or hinged knife, the coil was cut up into short lengths, each of the requisite size for one head. I fancy you would not have liked the job of slipping each wire into its little bead-like head, yet this was done with considerable rapidity by those well practised in the art. They were not threaded, indeed, one by one, but the workman used to put a number of heads

into his apron, take a bundle of pins in his hand, and by a little shaking and manœuvring pick up as many heads as he could. The pins thus loosely headed were in succession placed under a punch worked by the foot, and one blow completed the process. Whether the head thus arranged was firmly fixed, some of us who are no longer boys know pretty well. In point of fact, they continually slipped either wholly off, or too far on, leaving the naked wire to hurt the fingers. I have often wondered, when pins were made, why soldering was not tried, the shank being dipped into melted tin before the head was put on, and both heated for a second afterwards. Luckily, however, I did not patent this brilliant idea, nor another of equal value, viz., to form the head of a drop of solder, and finish it under a punch; for all at once it occurred to one Wright (I believe) of Derby to form the head as a blacksmith forms that of a nail—hammering it up from the solid metal of the shank. I can remember the first appearance of these solid-headed pins, which, like red-legged partridges, soon drove their weaker brethren from the field. Several machines for the above purpose have since been protected by patent, for it is, of course, possible to vary the details considerably; but the main working parts, and the principle of action, are the same in all. A few months since, we visited a pin manufactory in Birmingham, in which they manufacture all sizes,

from 3 inches down to about $\frac{1}{4}$ or $\frac{3}{8}$, baby pins or minikins, yet as beautifully finished as the larger ones. As you stand in front of a long row of these machines, you see pins falling rapidly into boxes from a long spout or shoot, pointed, headed, and complete, except in polish and colour. There were, perhaps, ten machines in the row, each disgorging about 300 pins every minute, and requiring hardly any attention. Rather noisy they are, these pinmakers; but so are boys, and if both do their work satisfactorily, I suppose we must not expect them to be over-silent. It was a perpetual click and hammer—fairy blacksmiths forging nails with the utmost regularity and precision. Having taken a general view, and picked up a handful of pins, to see if they were all alike well made, we proceeded to search for details. First there is the feed, on which the machines are to exercise their digestive powers. This is represented by a bright coil of brass wire coiled on a conical wheel or drum, which revolves freely on its upright axis at the back of the machine, at its upper part. The wire, as it leaves this drum or swift, passes through a double row of pins fixed in a zigzag fashion, so that it is bent in its passage first to the right and then to the left; and having had enough of bending, it issues from the pins quite straight, and begins its eventful journey.

What that journey is we will endeavour to describe

with the aid of a drawing or two; but the details of pin-making machines vary according to the many patents by which, from time to time, the different contrivances for pointing, heading, cutting off, &c., have been protected since Wright's first invention was established in 1820. The simplest way will therefore be to give a plan of the different parts, omitting the framing, and not confining ourselves precisely to any single patented machine. The several processes will be—(1) Straightening the wire; (2) drawing forward enough for one pin; (3) holding it fast that (4) it may be headed; and it has then (5) to be cut off, (6) pointed, and then lastly delivered into boxes or baskets as a complete pin, requiring only to be whitened, finished, and packed for sale. A single machine now accomplishes the whole of these operations except the two last, viz., the whitening and finishing. The insertion into papers in rows is now done by machinery also. The brass wire is wound upon a slightly conical reel (A, fig. 54), which revolves upon an upright axis or pin fixed at the back of the machine. This may be called the "feed," which is rapidly drawn into the insatiate maw of the machine, to be metamorphosed into the article in question, which article we take as the representative of inappreciable value, simply because the supply is so prodigious. To obtain such valueless article has, nevertheless, cost a mint of money, and much wear and tear of mind and brain.

The wire is drawn from the reel, or "swift" as it is technically called, by a pair of rollers or cams BB, revolving on an axis in the direction of the arrows. These rollers have each a flat face in one part of their circumference, so that as they revolve they clip the wire and draw it forwards until these flattened parts face each other and let go their hold, beginning again to grip the wire when the flats have passed. Thus their united action is to draw forward a certain length—release it—and then repeat the process until all the wire has been unwound. The wire thus sent forward is now gripped between two dies or jaws EE, which separate from each other by a spring, until a cam F in its revolution brings them together, and causes them to hold the wire firmly. The time of action of the cams is so arranged that these dies grip the wire just as a very little of it projects beyond them at K, at which moment the

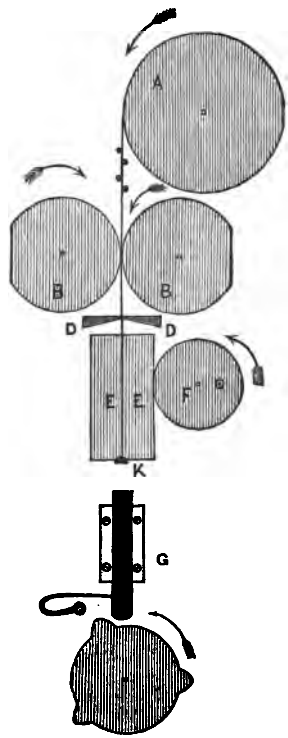

Fig. 54.—Machine for making Pins.

pair BB cease to draw it forward, and the cutting dies DD advance and sever this length from that on the reel. At the same moment the punch G is made to strike the projecting end by the action of cams, or tappets on the disc, completing the head at three blows. The dies EE instantly fall back, and release the pin, which only requires to be pointed. When it is considered that 300 pins are thus completed in one minute, the speed and exactness with which these various operations have to be carried on only serve to show the perfection of the mechanism employed.

But the pointing has still to be done, and is effected by the same machine. As soon as the grip opens, the pin falls into a kind of trough below, which inclines just sufficiently downward at one end to carry the pins forward by their own weight, aided by the continual shaking of the machine itself. This trough inclines to the left, turns at an obtuse angle, and comes back along the front of the machine. It has a slit extending its whole length along the bottom, which slit is just sufficiently wide to allow a pin to drop through as far as the head, so that it will travel along its course point downwards. In this position, therefore, the pins gradually pass onward to the front; and as they pursue their appointed course they come in contact with a long grindstone of a cylindrical form, or slightly conical, which

revolves in bearings in the forepart of the frame. As they hang in contact with this, they are made to rotate on their own axis by a bar, against which they lean as they hang, and which traverses to and fro, lengthwise. They are thus pointed very evenly, and pass on till they fall from the end of the trough into a box or other receptacle placed to receive them. Little *people* often make a great noise in the world, and not seldom do but little real work, and that of an inferior kind; but these little *machines*, of which a number are placed side by side, are of the very noisiest, rapping with tenfold the vigour of the spirits who are wont to amuse themselves thus, but doing their work so well that you may search among a bushel of pins and hardly find one that is incomplete.

The pins, thus completed as regards head and point, are of course still of the yellow colour of the brass wire from which they were made, and if left in this state would very quickly become tarnished. They are therefore first of all scoured in sand, and then tinned by being boiled in a solution of tin and bitartrate of potash, after which they are dried in bran with friction, which leaves them as white and bright as silver. Nothing now remains but to pack them in boxes made in a similar way to those described in the chapter on steel pens, or to stick them into folded papers. The latter work is done in a machine in the following manner; but the operation,

though easy to understand if seen, is not so easy to describe. The pins, first of all, are thrown upon the surface of a kind of sieve from a hopper or box, into which they are cast higgledy-piggledy—heads and tails anyhow. By a shaking motion something like that used in a thrashing or winnowing machine, they gradually roll down a slope to the further end of the sieve. This sieve has only bars running lengthwise, not across, and these are close enough to prevent the pins from falling through, so that they all hang by their heads, point downwards. Thus they are now all in position alike, heads up like soldiers, tails down, and thus they advance in ranks down the inclined surface of the sieve. When a row arrives at the bottom, a bar or plate descends and separates the end row from the rest, holding it fast in position, while the paper, already creased and folded in another part of the machine, advances against the points and is pierced by them. Another simple movement drives them home.

In pin-making machinery there are several differently constructed machines used by different manufacturers, and inventors are constantly devising new methods and new arrangements for accomplishing the end in view. And in this case some have contrived a machine in which the pins lie flat on their sides in parallel and horizontal channels, instead of being suspended vertically by their heads. It is capital exercise of the inventive talent of boys to con-

trive to effect in one way what others have done in another, and our young readers may now set to work with paper and pencil, and try to plan a pin-machine, or paper-sticking machine, for themselves.

If they have skill to construct a model, it will tend to show them how many little details must be rigorously attended to, before any invention can be successfully completed. They will learn also that, in all machinery, the greatest degree of accuracy is needed in shaping and fitting the various parts. A "bearing" out of square, a hole drilled with what may seem trifling inaccuracy, a wheel not mounted at right angles to its axle, will not only be a witness against the maker of bad workmanship, but will cause the action of the machine to fail altogether, and may possibly induce the inventor to cast aside as a failure a design which was in reality of great value and importance. Accuracy in drawing a design is not by any means less necessary than accuracy in a model, or in a machine. Indeed, it is in our humble opinion the one lesson to be learned by the mechanic before all others. He must never be content with "almost a fit," or "almost true to scale." From the very commencement of his boyish career he must determine to do always first-class work, or he will fall into the ranks of the bunglers, whose carelessness and inability are stamped upon all that they do.

CHAPTER XII.

HAIR-PINS.

A HAIR-PIN is a simple enough article, and withal a cheap one—a bit of wire bluntly pointed, and doubled in the middle. But examine it, and try if you can design a machine in your own mind to make one, a machine that shall be competent to turn them out by thousands of any given length, all bent exactly and uniformly in the middle. I know of no better exercise than this for boys of a mechanical turn of mind. Let them take up any simple article of everyday life which they have not actually seen made, and let them take pencil and paper, and try to hit off a machine that will do all that is required. All such machines are actuated by levers and cams, of which we have already spoken, and it is the cunning arrangement of these which gives motion to the several parts, and causes each to do its special work at a given moment.

Now, to make a hair-pin we require to straighten the wire, gauge it to a certain given length, cut it off, point the ends, and bend it accurately and roundly in the middle. The straightening is always effected by dragging the wire between pins put zigzag fashion in a board or metal plate. These, by bending the wire this way and that, as it passes between them, take out the curl it had acquired from being wound upon a reel, and deliver it quite straight for any further operations required to be effected upon it. But even in this there is a little skill

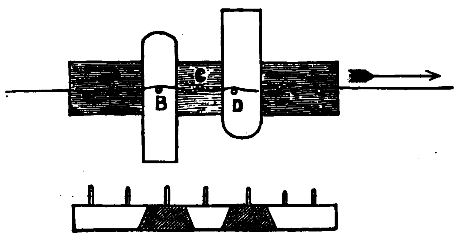

Fig. 55.—Straightening Wire.

necessary in order to arrange the pins correctly, and therefore they are not absolutely fixed in one plate, but in two or more, so as to admit a certain degree of adjustment, *i.e.*, they can be made to stand quite in a line, or at various distances on either side of it. In fig. 55, one or more of the pins B D is fixed in a plate that slides in a direction at right angles to the general line of the pins, which enables them to be fixed in the position found by repeated trial to be the best.

After leaving the pins, the wire passes through a guide-hole in a block of metal to the feed apparatus, which draws it along until its end touches a stop-plate in the point of the machine, and determines the length required for one pin. This is something like the feed of a sewing-machine in appearance, only the stitch is rather a long one. What is, however, the " cloth forwarder" in the one, is more of a *vice* in the other. We can perhaps make the action clear by giving it separately.

Let the plate AA (fig. 56) slide between guide-bars CC

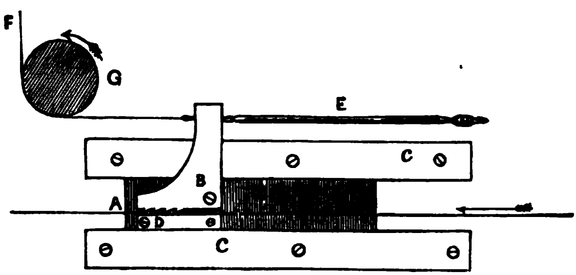

Fig. 56.—Feed Action.

fixed to the top-plate or bed of the machine, and let there be a thick piece D firmly screwed to it to form one side or jaw of the vice. B is the opposite jaw, of the shape here shown, and it turns on a screw or pin near the angle. On the face opposite the fixed jaw there are a few teeth pointing towards A, and of the same shape as the teeth of an ordinary handsaw, so that the wire might be pulled forward

in the direction of the arrow easily, but would be caught by the teeth if attempts were made to pull it in the opposite direction. E is an elastic indiarubber spring; F is a catgut or wire band passing round a pulley G, and then to a crank of considerable throw fixed to the upper revolving axis of the machine. By the rotation of this crank the band F is alternately pulled and released; and when released, E pulls the jaw B and the sliding-piece A in the contrary direction. Now, owing to the form of the jaw B, and to the fact of its being hinged near its angle, the indiarubber band will open it, and release the wire; but a pull of the band F will first close the jaw upon the wire, and then pull the slide itself forward, carrying a length of wire with it. As soon as the crank which effects this has passed its centre, the elastic band pulls back the slide, and at the same time opens the jaw of the vice which passes along the wire, but does not now take hold of it; and this backward motion will continue until, by its semi-revolution, the crank again exerts a pull upon the vice and slide. Thus it is that the vice brings a certain length of wire forward, and then goes back open jawed for a new supply. There are two ways of regulating this movement, so that the wire shall be just the right length. The crank may be adjustable, as explained in the description of the planing-machine, so as to lengthen or diminish its throw at pleasure; or the wire

coming against the stop-plate, may be made to throw the feed action out of gear. Either will of course regulate the length of wire to be cut off for a single hair-pin; and this cutting off is the next operation, and it is effected in the following manner: The knife is like one blade of a pair of large shears, the handle being very long, and the cutting part short, to give leverage. The cutting edge works close against a fixed piece of steel, which practically forms its other blade. Upon the same axle that carries the crank, and forming a continuation of its base, is a projection constituting a cam (A, fig. 57).

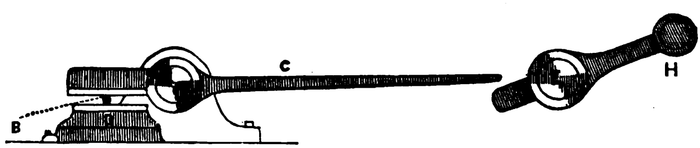

Fig. 57.—Shears or Guillotine.

This cam at each revolution engages with the long arm of the shears, and forcibly depresses the short end, causing the latter to descend upon the wire and cut it off, as will be understood easily by the aid of the drawing. These shears come into action the very instant the jaws release the wire and the latter touches the stop-plate. This stop is adjustable, and can be placed at any required distance from the cutter. A, the cam; H, crank; C, long arm of the shears; D, the fixed jaw; B, the wire; and E, the axle

on which the crank is fitted. Hair-pins, though made rapidly, are less quickly turned out than ordinary pins, not being required in such great numbers.

We now have simply a length of wire cut off, but not pointed at either end. The next movement is a very curious and ingenious one. The wire has to be *rolled* forward upon the bed of the machine, that it may be sharpened at each end at the same time by the action of a pair of emery wheels or grindstones, revolving at a rapid rate, one on each side, these being put in motion by two bands passing from a large flywheel below. Another crank is the prime cause of the advance of the wire, and this gives motion to a flat rubber, which is made to press on the wire as it rests upon and passes over it.

This slide and rubber are represented in fig. 58. There is, first of all, a slide A, working to and fro upon the bed of the machine upon guide-bars D. This slide has fixed upon its upper surface bearings BC. The end of the connecting-rod from the crank K is hinged to one of these at B, and the tail of the lever, which forms part of the rubber H, is hinged at C. By the motion of the crank as it revolves, the slide A will be moved to and fro upon its guides, carrying also with it the rubber H, and this resting upon the wire *f*, will cause it to roll over and over beneath it, carrying it forward; but also, on the return

stroke, carrying it backwards. Now, this latter motion has to be got rid of, because when the wire has been carried towards *f*, it requires to be released, that it may fall across a pair of hooks, of which one is seen at *g*. Hence it is that the rubber itself is hinged at C, instead of being made part of the slide A. Thus arranged, the tail-piece rests upon the end of the connecting-rod, shown again at M on a larger scale; and as the crank advances and recedes from the rubber, the end of the connecting-rod oscillates up and down, alternately raising the tail-piece

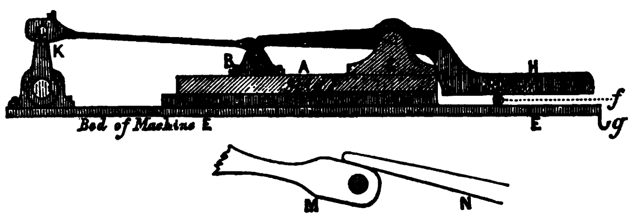

Fig. 58.—Slide and Rubber.

of the rubber and allowing it to fall by the action of a spring not shown in the drawing. As the slide recedes, therefore, the part of the rubber resting on the wire is slightly raised, and is again lowered as soon as the wire next cut off is ready for its action. Each wire is thus rolled forward under pressure until it falls off into the pair of hooks *g*.

We have already stated that during the forward-rolling motion of the wire its ends are brought into contact with

a pair of rapidly-revolving grindstones. These are in such a position as to have only a very small part of their circumference above the level of the bed of the machine, so that they act only on the extreme ends of the wire, and render it conical and bluntly pointed. This will be easily understood without any additional drawing. The wire thus pointed now falls off the bed on which it lay, and

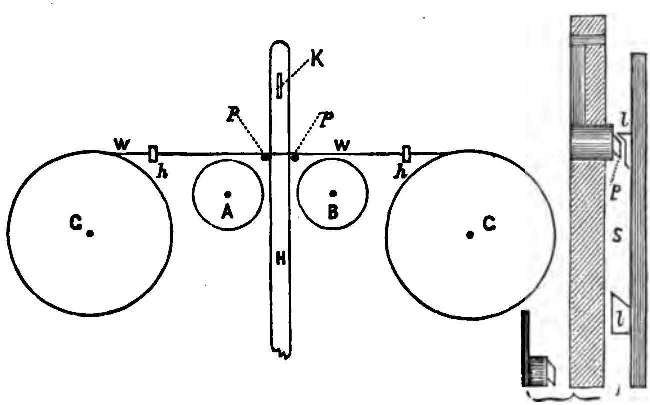

Fig. 59.—Action of the Bending-Tool and Grindstone.

rests in two small hooks attached to the front of the machine, and its centre is then over the space between two grooved pulleys A and B (fig. 59). In this drawing WW is the wire, *hh* the hooks on which it rests; it also lies on two pins *pp*. The grindstones are shown by the circles GG. H is an upright bar which we may term a plunger, and it works vertically up and down by means of a crank

and connecting-rod attached to it. Upon its face next the wire is a projecting knob K, which, as the plunger descends, comes down on the wire and bends it, carrying it between the pins *pp* and pulleys AB. The actual bending-tool, or knob K, is not attached to H as one with it, but is made to fall into a recess in the plunger so as to lie flush with its face, until, by the action of a stud in a fixed bar in front, it is pushed out so as to act on the wire, a second stud again driving it back into its recess, and so enabling it on its ascent to pass by the wire without coming into contact with it. The plunger and its projection or bending-tool are drawn separately at S, which is a side view of it. In this is seen the projection *p* on the opposite side of the bending-tool, which comes into contact alternately with the fixed studs *ll* upon the stationary bar in front of it. The angular sides of the slides cause the peculiar action required, one pushing, the other pulling the bending-tool by means of its hook and wedge-shaped attachments.

Whether we are read by any of our boys' sisters we can hardly tell, but if so, *they* will know at any rate of such modifications of hair-pins as are brought out from time to time; and, among others, of the corrugated form, in which the two legs are wavy instead of straight, being supposed less liable to fall from the head when

made in this way. This is done in a very simple and ingenious way, by merely using rollers and a bending-tool with corrugations on their sides, instead of smooth ones as shown in fig. 59. When these are used, they are arranged to turn on their axes and bring the corrugated parts gradually against the wire, a spring drawing them back immediately. The corrugations, as seen in fig. 60, which represents the machine as seen in front only, extend round a part of the circumference of the pulleys. Such is the machine in all its principal details, by the aid of which tons of wire are converted into hair-pins for the use of the ladies; and though comparatively simple, it is nevertheless a very cleverly-devised machine. We have added here lettered references to its several parts.

AA, the cast-iron stand. B, flywheel on the main shaft. C, crank on the same shaft to give motion to the plunger F, through the medium of the connecting-rod D. EE, fixed guides in which the plunger works. II, grindstones worked from the flywheel by two cords not shown. MM, corrugated pulleys, as described. G, upper part of plunger, in which the bending-tool is fixed. H, fixed bar holding the angular studs projecting towards the plunger, as represented at S in fig. 59. LL, springs acting upon the corrugated pulleys, as explained. KK, elastic cord attached to the

feed R, to the opposite side of which is fastened the cord passing over the pulley J to the long crank Q actuating

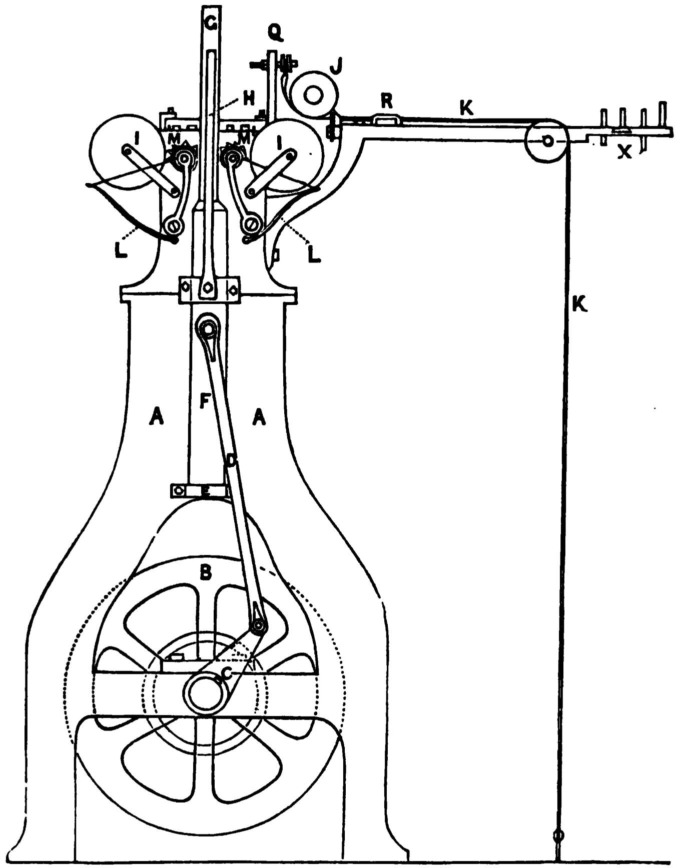

Fig. 60.—Hair-Pin Machine, front elevation.

the feed. X, straightening pins, one of which is fixed tc

a cross dovetailed slide, to render it capable of adjustment.

The whole of the movements required for the action of the different parts are obtained, it will be observed, from one main shaft and driving-wheel; the second shaft and crank at the upper part, which actuates the guillotine and feed motion, not performing more than a partial revolution upon its axis, as it is only required to have a to-and-fro motion, and this is obtained from a crank upon the axis of the flywheel, from which a connecting-rod with a double or block joint extends to this second shaft. There are a few minor details which a maker would require to have specified, but the above will, we think, suffice to make plain the action of this machine.

CHAPTER XIII.

SHEET-METAL GOODS.

THESE are even more numerous and more varied in form and character than those which are forged or cast, and there is a wonderful amount of ingenuity exercised in their manufacture. Most of our young readers have probably stood beside the tinker and watched him at his work, or paid a visit to his superior fellow-craftsman, the tinman; and they are, therefore, tolerably conversant with the mysteries of soldering up pots and kettles and saucepans, which are cut out of sheet tin, and hammered into shape upon anvils of various forms and sizes, and which are called by various names, according to the special work for which they are designed. These processes are, after all, very similar to, and not of much greater difficulty than, modelling on paper and cardboard, in which gum replaces the solder and a pair of scissors the tinman's shears. But the process now about to be described is one that cannot be

carried out in this material, and consists in forming bowls and teapots, candlesticks, and other articles out of sheet metal folded, but not soldered; and in which there are neither seams nor creases. For shallow and open work, this is effected by the use of stamping-presses and dies of various forms—some of enormous power; but other works are made by a process called spinning.

Among the articles made by stamping are baking-dishes, meat-covers, silver dishes, spoons, ladles, and such-like; while teapots, candlesticks, sugar-bowls, and such hollow ware as is bulged out, and therefore smaller at the mouth than elsewhere, are very generally made by spinning in the lathe. At first sight it would appear impossible by any process to convert a circular flat sheet of block tin, pewter, or other malleable metal into a teapot without any join. In fact, the same difficulty would seem to exist in making the little tinned-iron vessels called tart-tins, in which obliging cooks bake jam tarts for voracious schoolboys; because it would naturally be expected that the metal would crease and pucker, the same as paper would, if we were to take a circular disc and turn it up all round. Such, however, is not the case under proper management. To understand the generally accepted theory of this, a plate of metal must be supposed to be made up of an infinite number of minute particles or grains, which in a state of rest are held together by

mutual attraction, but may by the application of force be separated and made to move about amongst each other and take up a different arrangement. In the present instance the power used is the stamping-press. Malleability, or the capability of being spread out by hammering, which is the property of gold and silver, tin, lead, and some other metals, may rest upon the fact that their constituent particles are thus capable of readjustment as to position, without losing their mutual power of attraction; brittle metals, having less of this innate cohesion, allow a complete disunion of their particles under a blow. If such is the case, it is easy to understand that the particles of metal which would otherwise cause plaits or puckers glide over each other, and become so rearranged as to produce a perfectly smooth and even surface. Such is the theory accepted by scientific men, as accounting for facts otherwise incapable of explanation. The simplest form of hammer and die work is that by which a tinman hollows the lid of a kettle or makes a scale-pan. For this purpose he cuts a round disc of tin, and lays it upon a hollowed bit of hardwood turned out in the form of a bowl, and with a boxwood mallet, rounded at one end, he hammers the tin while it rests upon the block, until it gradually assumes the desired form. During this time he turns the piece of metal about in all directions, correcting any tendency to pucker which it assumes, and regulating the

strokes of the hammer accordingly. This requires but little skill or practice if the work is shallow, and any one of our young mechanics would succeed almost as well as a professional workman. An ordinary thimble is but a deep and narrow cup, the principle of its manufacture being the same; but the deeper the article is, the more gradually the work has to be done, to avoid the unpleasant contingency of knocking a hole through the centre of the disc of metal, instead of inducing it to take the desired form—a mistake that, no doubt, sometimes occurs even with skilled workmen, if the metal is not of good quality, or has been insufficiently annealed. For the action of a hammer upon metals is to consolidate the particles, and render them hard and brittle, and it becomes necessary to soften them by repeated heating and gradual cooling; or no deeply-recessed articles could possibly be made by stamping or rolling. In making dish-covers, therefore, and other similar articles, the metal is first placed between dies only slightly recessed, and, after their form has been imparted by a few blows, the sheet of metal is passed to the annealing-furnace, and then compressed between more deeply cut dies, and the operations of stamping and annealing are again and again repeated alternately, until a sufficient amount of relief is given to the article. The dies are of steel, and are recessed chiefly by hand, so that the cost of a set with

an elaborate pattern is very considerable. Special designs, moreover, are registered, and are the property of the designer, or of the manufacturer for whom he works; for most large establishments keep artists upon the premises whose whole work is to invent new patterns for their employer. A visit to Elkington's suffices to prove how worthy of the name of Artist these trade designers are, who nevertheless simply work at so much per annum to supply food and clothing to themselves and their families. They are, in fact, many of them, men of whom the outer world knows nothing, and whose exquisite productions bring credit and honour and wealth to their employers, while their own names are absolutely unknown; yet this order of things, unfair as it may appear at the first glance, cannot very easily be reversed. The busy and well-educated brain may be capable of designing, but after all the pocket of the capitalist only can bring its productions into the market, and the employer and employed are thus mutually benefited. It must not be supposed, either, that artistic talent of the class alluded to is badly paid; certainly not by the leading manufacturers, who not only appreciate high art, but are always ready to give handsome remuneration to secure it. A great majority of these artists are foreigners—chiefly Germans and Italians—for somehow or other John Bull has scarcely so good a head for originating an elegant design as he has for devising

the means of carrying it out in practice, and making it remunerative. Our schools of art, however, are trying hard to put Englishmen on a better footing in this respect, the rules of art and design being now satisfactorily taught by the most able professors of the day, and it is to be hoped that ere long our own countrymen will be better able in this respect to compete with foreigners. Probably, however, high-class artistic talent may prove to be in some sense national, and that our capacity for it is somewhat limited. If so, we must still be content to import design, and rest satisfied if in actual manufactures we are able to distance all competitors. Even now our position is a tolerably high one.

Among the articles of daily use, which are to be seen in every house, made of sheet metal by the process of stamping or spinning, not one perhaps carries more deceit on its face than the ordinary door-knobs of brass. Like many human faces of smooth and sleek appearance, they appear to be what they are not. Looking solid, there is nevertheless little solidity about them. The part next to the lock, through which the small screw passes which secures it in its place, is a solid casting, with a square hole through it to receive the iron spindle by which the bolt is drawn back. This is turned in the lathe, with a groove at the end next the knob, which is dovetailed in shape, *i.e.*, the brass is left larger at the outside of the

groove than at the inside. Thus anything made to fit the groove could not be pulled off in either direction. The knob itself is cut out of sheet brass as a flat disc by one blow of a stamping-press, and by the process of alternate annealings and stamping between suitable dies it is first rounded and made like a half globe, and then ultimately folded so closely round the casting that its edge clips the groove turned in it. The whole is now polished in the lathe, and comes forth as if one solid knob of brass. It would at first sight appear as if it would be far easier and less expensive to cast the whole in one piece, but in reality so rapid and easy is the process above described, that the apparently inconsiderable saving effected in quantity of brass needed is of sufficient importance to make this hollow work the least costly and the most remunerative to the manufacturer.

CHAPTER XIV.

SCREWS, BOLTS, AND NUTS.

NO doubt our young readers have made use of these in their more or less successful attempts to rival the carpenter and blacksmith; but probably it has never occurred to them to inquire by what means they are produced in such numbers, and so well finished. Wood screws especially, which are now so clean in thread and so nicely tapered, can hardly fail to have attracted a certain degree of attention, especially if comparison of them has been made with any of more ancient date, with their blunt ends and generally rough appearance. Here, again, is the result of well-arranged machinery cunningly devised and scientifically applied. In old days screws were produced by hand only, chiefly by women and children, who produced the thread by very imperfect means, after husbands, fathers, or

brothers had forged the blank. If a screw is examined, it will be seen to consist of a head with a slit across it for the application of the screwdriver, by which it is driven into the wood—a shank, turned or otherwise formed, quite smooth and round—and a threaded or screwed part, sometimes of equal size throughout, but now generally taper towards the point, that it may be capable of being driven into the softer woods without the previous use of a gimlet. Now in old times these were produced as follows: First of all, a rod of iron of the requisite size was heated at the end in a forge fire, and when taken out was drawn down as a nail is forged by the blacksmith, but not so much as to form a point, the object being to produce a cylindrical blank with a blunt end. As this required to be of as nearly equal size as possible from end to end, it was finished between dies by help of a simple tool called an Oliver—but I know not how the tool obtained its name. Perhaps it will be understood without a drawing, as we have already trespassed somewhat heavily on the engraver. Imagine two upright posts, driven securely into the ground a short distance behind an anvil, and 2 or 3 feet apart. Between these, turning at each end on gudgeons, was mounted a roller hooped with iron at each end, much the same as the axle of the wheel of a common garden-barrow, which, if a little longer, would fairly represent the roller in question.

Instead of the spokes, imagine the end of the handle of a sledge-hammer to be inserted in the central hole, and so arranged that when this handle was horizontal the hammer's head would rest fairly upon the anvil. Overhead was a spring pole of ash or other suitable wood, from which a rope or chain descended to the handle of the hammer, so as to lift it about 2 feet from the face of the anvil. Now, imagine a short arm or spoke on the right hand of the hammer-handle, and a short distance from it, from which also a chain descended to a treadle by the right foot of the workman. By means of this treadle and short lever the hammer could be brought down with great force and rapidity, and after each stroke it would be raised up again by the spring pole from the face of the anvil, on which it would fall each time at precisely the same spot. This contrivance took the place of the second man or boy, usually called a *striker;* and I can only suppose that some ingenious young shaver of the name of Oliver invented this contrivance to save his own labour while he sat down to eat lollipops or plan mischief. At any rate the machine, simple as it was, showed ingenuity, and was a very efficient contrivance for the intended purpose. But though the arrangement as we have described it is correct up to a certain point, the end of the sledge-hammer and the anvil were formed respectively as two halves of a die in which the iron would take the

required cylindrical form, both being hollowed out with a semi-cylindrical groove, so that when placed in contact, a perfectly cylindrical cavity appeared of the exact size of the shank of the required screw. Any number of blanks formed in these dies would consequently be precisely similar. The shank having been thus formed by a few rapid blows, the bar was cut off a little above it, and the head also formed by a few blows, while the blank was suspended by it in a "heading tool," which was merely a steel block with holes in it of the form of the head required. All this was done at one heat, and before the iron had time to cool below redness. These rough blanks were next passed to the turner, who, with a lathe specially adapted to the purpose, took off the rough outside, and perfected the shape of the head. There was another way, however, of forming the head as well as the shank, which is used at the present time by gunsmiths, and others who have frequent occasion to make their own screws. A cylindrical block of steel, with a tail-piece or projection, to enable it to be held in the vice, is bored with a hole of the exact size of the shank of the screw—a little less, therefore, than the size of the forged blank. The edge of this is then filed into teeth something like very large file-teeth, and the hole is also enlarged at one end, and this also is similarly cut round with teeth. A blank is taken, and a saw-cut made across it for the screwdriver, but the latter

is put into the end of a brace—the smith's brace and bits. With this the screw-blank is driven through the grinder, and its head and shank are, at a single operation, beautifully turned and finished. A somewhat similar process was used to form the screw-blanks, but the dies were in halves, and made to spring open and drop the blanks as soon as the turning of their shanks was accomplished. There were from time to time various improvements made and patented whereby the process might be expedited and the work more satisfactorily accomplished, but these need not be entered into here. A visit to the Patent Office Library in Southampton Buildings, London, would do far more than we can do here in teaching the young mechanic the various ingenious modifications of the screw-blank machines of the days of their forefathers.

The screw-blanks had now to be threaded, and this work was carried on at the homes of the workmen, who were paid by the gross. The result of the inefficient appliances used was a very inferior quality of screw, which, however, found an ample market when nothing of a superior kind could be obtained for love or money. The thread of a screw may be formed, and was formed for some time, by a screw-plate, *i.e.*, a plate of steel with a hole in it, which had a thread cut inside it by means of another screw or tap made of hardened steel. After such thread was cut, the plate itself was hardened, and would

form a thread upon any metal softer than itself. But this thread was of little strength, because it was *burred* up and not clearly cut, and in all screws made thus (and the process is used constantly for small screws) there is this fault still prevalent. But if a thin file or small metal saw is inserted into the hole in the screw-plate, and two or three notches are cut quite through the threads into the plate beyond it, we obtain certain cutting edges at each notch, besides places for the escape of the metal shavings formed during the process. Screws, therefore, made by such a plate are very much better, because the thread is partly cut and partly formed by the compression of the metal. But by a further improvement the screw-plate was replaced by dies.

Suppose the plate made of steel, half or three-quarters of an inch in thickness, and after being drilled and tapped, sawn through so as to divide it across the centre line of the hole, a pair of screw dies would be formed, and if these were placed opposite to each other in a proper clamp or holder, they could be tightened on the blank as the work proceeded. It was by similar dies the blanks were cut with a thread in the wood screws we are describing. The blanks were fixed one by one in a kind of chuck in a lathe-head, and the dies, standing open, were made to enclose it, and gradually brought together until the thread was as deep as required. It was a toler-

ably quick process, but the head was turned separately, and altogether the screws could not be made very cheaply, unless the work was too rapidly and carelessly done. No other plan, however, was made use of for many years.

But some ingenious individual, whose name, however, we do not know, conceived the plan of making screws of wire, similar to the way in which pins are made, and which we have already described in this volume; and although, of course, the various parts of the machine needed great strength, owing to the fact that the wire for the larger screws required to be of considerable size, this plan has now superseded entirely the old method of making the screws by hand. The process is precisely that of pin-making as regards the formation of the blanks, but the grindstone is no longer needed. The wire is drawn from the swift, or reel, cut off by a guillotine action, and the head formed by two or three blows from a suitable punch. The blank then drops into a box or other suitable receptacle, in which it is conveyed to another machine difficult to describe, but of great ingenuity. Imagine a revolving wheel without a rim—a wheel, in short, with spokes only, each spoke being forked at the end. These forks dip into the reservoir of screw-blanks as the wheel revolves upon its axle, and picks them up one by one by their heads, and in addition carries them

past a small circular saw revolving at great speed, which in a moment cuts the nicks for the screwdriver. The blanks then drop into a basket ready for further operations. They are now placed in a lathe-chuck one by one, and instead of being screwed by a pair of dies, they are made to traverse to and fro, while a fixed tool cuts the thread deeply and cleanly, leaving it quite sharp and bright. Even *this* description, however, of improved mode of manufacture hardly gives an account of to-day's screwing machinery, so rapid have been the changes of late years, and to such high perfection has the machinery been brought. In fact, there is now little left for the exercise of the skill of workmen, who are only called upon to empty buckets of screw-blanks into the various hoppers, from which they are delivered into the machines by automatic action,, and are turned, cut, nicked, and screwed by a succession of mechanical contrivances without any intervention of the human hand.

The improved machinery, of which Messrs. Nettlefold & Chamberlain of Birmingham are the chief proprietors, was originally introduced into this country from America, which has supplied us with so many inventions for the supersession of hand labour. From America came the plan of using tapering blanks, and making the screws with sharp points, like that of a carpenter's gimlet, which, on the whole, was the most valuable of all the

improvements made from time to time in these well-known little articles of daily use.

Of late wire nails have come into extensive use. They too originated abroad, and may be seen in fig-boxes and similar cases from Turkey, France, and elsewhere. They were introduced in the Exhibition of '51 as Russian nails, but whether invented in that country or not, we cannot say. No doubt the idea was gained from the pin manufacture, as it was comparatively an easy matter to make similar machines of more solid construction strong enough for these nails, or for screw-blanks. They are easily driven into soft wood, and not being wedge-shaped like the forged nails, have no tendency to split the material. If one of these nails is taken in hand, the grip of the vice-like clams by which they are held while being headed will be easily seen, as no care is subsequently taken to obliterate it; and the roughness thus formed just below the head no doubt adds to the security of hold which they take in the wood. They are even, in spite of this, rather too easy to draw, but are very handy to use, besides being very much lighter and of less bulk than ordinary nails. Pins, nails, and screws depend, therefore, it will be seen, upon machines of precisely similar description, and are turned out not only of very beautiful finish, but in such abundance as to be cheap enough for all to buy who need them.

How pins are made, and whence they come, we know,
But it remains a mystery where they go.
Millions are yearly made, and yet how rare
The cry, "Behold, a pin is lying there!"
One solitary pin! alone upon the floor,
Where we should have expected half a score;
And even if we searched the dustman's bin,
'Tis ten to one we shouldn't find a pin.
And yet they go, soon lost to sight and sense—
'Tis well they can be bought at small expense.
But 'twas not always thus—in years gone by
To own a pin was quite a luxury.
"Pin-money" then was claimed by every dame,
And husbands found 'twas no mere empty name;
But in *these* days husbands would gladly pay
For pins to use and pins to give away,
If "pin-money" required by wife and mother
Did not say one thing while it meant another;
But count the cost, and husbands cry, "God bless 'em!
Our wives must need a lot of pins to dress 'em;"
For pins, though cheap, imply a lot that's dear
(Mysterious items of a lady's gear)
To stick them into. Dressmakers can say
For what *et ceteras* pin-money must pay,
Such things we know not—and we dare not ask.
Ours is an easier, more congenial task,
To teach how pins, and nails, and screws are made
To meet the stern necessities of trade;
This is a pleasant subject—but the other
We gladly leave to bride, or wife, or mother.

Having, however, been beguiled by our very troublesome and not very polished muse to go astray somewhat from the even tenor of our way, we must return to our sober, prosaic statement of facts about screws, with which we have as yet hardly done. Passing from the wood

screws used by carpenters, the formation of which we have now described, we may turn our attention to the manufacture of bolts and nuts, of which, since the establishment of railways, the number required every year is simply beyond calculation, and gives employment to the operatives in many large factories in the hardware districts.

SCREWS, BOLTS, AND NUTS.

These are, indeed, things of daily use. Not a machine can be made without a number of them, and if you were to walk along the railway, you would see, at the junction of every rail with that next to it, an iron plate, called a fish-plate, on each side, with four screw bolts and nuts to keep all secure. This will give you an idea of the enormous number in use—and indeed *number* is not considered, for these things are sold by the ton. Now, in order to give an idea of what is meant by a *labour-saving* machine, I shall first tell you how bolts and nuts are made by hand, which a few years ago was the only method known, and then I will describe the present mode of operation.

To begin with the bolt. If the head was to be very large in proportion to the size of the shank, the smith took a rod of iron the size of the latter, heated it in his forge fire, and cut it off, probably by help of an assistant or striker. He then took a rod of square bar,

heated, and bent it round the nose of his anvil until it had assumed the shape of a ring the size of the bolt. It was then cut off and placed over one end of the bolt, and both again heated to a welding temperature, and the two were then hammered until the union was complete. If the head of the bolt was to be six-sided, which was often the case, it was hammered on a swage-block, or block of iron with a deep notch in it, and turned over in this again and again until the head was properly formed. Then, as in all probability this process left the part in a very rough, unfinished condition on its upper and lower faces, these were rectified in a proper pair of swages after the bolt had been reheated, and subsequently the file was used to render the head complete. At other times, if the head was not required to be of so large a size, it was hammered and swaged up out of the solid metal, and thus made in one piece with the shank of the bolt, which had then to be screwed to the requisite length with stock and dies. The heading-tool was similar to that used for nails, namely, a bar of case-hardened iron or steel with holes in it, through one of which the shank was passed while the heated iron left on the upper side of the plate, and which was purposely left of larger size, was spread out on all sides by the hand-hammer; but for bolts the hole was square, to give that form to the neck of the bolt just below the head. This is always necessary in a screw-bolt, to

prevent its turning round under the action of the wrench used to tighten the nut. The Oliver already mentioned was a great improvement upon the ordinary hammer which had been hitherto used, both for forming the head and the shank, and for many years this was all in the way of machinery used in the manufacture of bolts and nuts. But as the demand for these articles increased, the need was felt of some readier method, and the ingenuity of inventors was successfully aroused, with most gratifying, because *practical*, results, and the whole system of bolt-making was revolutionised.

In the first place, the lengths of iron requisite for the bolts are cut off by a single stroke of a cutting-press, which only requires to be continually fed "from morn till dewy eve," and not unfrequently from eve till morn again. The short pieces thus produced are carried in boxes or on hand-barrows to a lad who stands before a furnace, the thick iron door of which is pierced with a number of holes, each of a size to receive a single bar. Into these holes the bars are placed, and while that part which rests in the holes is only partially heated, the short bit which is to form the head, being exposed to the full heat of the fire, soon attains a white heat. It is then withdrawn, and tossed to a lad or man who presides over the press which has superseded the Oliver. The lower part, or anvil, as we may call it, consists of a pair of

strong dies, which, when closed, form a square hole like that of a heading tool above, but a round hole of the size of the shank of the bolt below. In these dies each bolt is placed, and upon the heated end descends with irresistible force, but with a most deceitful quietness, a hollowed die of the form required for the head of the bolt—and in a moment the work is complete—the dies which hold it open, and a shapely blank falls out upon the earthen floor. The lad who attends the furnace has always a bolt at the proper heat for the heading-press, which he picks out of its cell the instant it is ready, supplying its place from the heap of bars at his side, so that there is never a moment's delay, and the supply is unremittingly kept up. The rapidity of the process is therefore exceedingly great.

The screwing of the bolts, which is in a great measure left to the superintendence of women, as there is little labour required from those who attend to the several machines, differs hardly at all from the method used in forming wood screws. The bolts are chucked in a machine similar to a lathe, and the cutting tool forms the thread upon it as it traverses. There are, as might be expected, modifications of the machine, but the principle is always, as a matter of course, identical in all. Either the tool traverses at a given rate, or the bolt; the speed of traverse depending on the number of threads required to

be cut in one inch of the length of the bolt. It is easy to understand how rapidly the above process of making bolts has superseded the old plan; one great advantage in all machine-work being, that any number of such articles can be made with perfect uniformity in size and shape. The threads, too, are cleanly cut, and very much deeper than those formed by the screw-stock of the blacksmith, or the dies hitherto exclusively used for this purpose. In some machines, however, recently patented in America, dies are again introduced, but of a far superior pattern to the usual kind. Of our own inventors in this department, Sir Joseph Whitworth stands *facile princeps.* Not only did he greatly improve the dies used with the screw-stock, but he introduced the system of standard pitches—*i.e.*, the number of threads to the inch is always the same for any given diameter of bolt; so that if a nut were lost from any machine, or any bolt required to be replaced by a new one, there would be no difficulty in matching the thread.

If we have, in the machines which I have described, instances innumerable of economy of manufacture—time and material being managed so as to ensure the utmost attainable profit—another kind of economy may often be witnessed in the doings of the workmen, of which the following is a sample: At the time of my visit to a manufactory of this kind the dinner-hour was drawing

near, and I had an opportunity of observing an ingenious and economical adaptation of means to a desired end. The camp-kettle being placed on the ground, the red-hot bolts as they fell from the machine were ranged neatly round it, thus supplying the heat required to boil the tea or soup without expenditure of fuel. This is ordinarily done by the men at each meal.

The nuts for these bolts are made in a similar way to the bolts themselves. A man, standing by a furnace or forge, places in the fire a flat bar of iron, of which he heats a length of perhaps 2 feet at a time. Close by him is a strong punching-machine, the cutter of which is furnished with a central pin to form a hole in the nut, and the punch and die, or block over which it rises and falls, are so shaped as to give to the nut its proper form when the cut is made. Thus at every stroke a nut is severed from the iron, bored, and finished, with the exception of the screw thread. During this operation a stream of water flows continually over the punch and nuts, which drop into an iron box at the rate of about fifty a minute. As two or three bars are kept at once in the fire, one is always ready to be drawn and placed in the machine The bolts and nuts thus made are next carried to the workmen and women whose office it is to cut the threads on each, and thus finish them ready for the market. The shop in which these final operations are performed is in

the form of a long well-lighted shed, in which screwing-machines are ranged in long rows, the whole being worked by a series of bolts coming down from a shaft overhead, on which a pulley is fixed over each machine. On the driving shaft of the latter is a fast and loose pulley, one revolving with the shaft on which it is immovably fixed, the other running easily upon it. To stop or start the machine it is only necessary to shift the strap from one pulley to the other. The nuts are here fed up to the tap one by one, and a single passage of the latter through them perfects the thread. I daresay most of our young readers have noticed that the old-fashioned square nuts are seldom seen now, even at the shop of the village blacksmith. These used to be cut with a chisel from a square bar heated to redness, and a central hole having been made through it by a punch, a thread was cut by a tap, and the whole was finished by a few strokes of a file.

These nuts were either weak or unnecessarily clumsy. The corners were strong but the sides weak, and if the latter were widened by using a broader bar of iron from which to cut them, the nut became so large as to be out of all proportion to the bolt. Hence the hexagonal or six-sided nut was introduced, which being the nearest possible approach to a circular one, gave equal strength at all parts of its circumference, while it enabled the ordinary screw-wrench to be applied, which was used pre-

viously for square nuts. But it is not every one who can file up correctly the six sides of such a nut, and, indeed, to do so is such a proof of skill in the use of a file, that it has been generally made a test for the candidates for the Whitworth Scholarship. Since the introduction, however, of machine-made nuts, the blacksmith has been able to purchase them of all sizes as blanks, and all he has to do is to cut whatever thread he may require by means of a tap. Sometimes eight instead of six sides are given to nuts, but though these are theoretically more perfect than the others, the ordinary wrenches, unless very well made, and in perfect condition, are apt to slip round without turning them, and the corners thus get rubbed off. Machine-made nuts being formed between dies, are beautifully made—somewhat thicker in the middle than at the edges, and with a raised circular surface on each side, which gives them the appearance of having been turned on each face in the lathe. This is, indeed, done to give them a more perfect finish, if they are required to be bright to match the machine in which they are to be used.

Having had occasion, in treating of bolts and nuts, to speak of the general use of pressing or stamping machines in their formation, I may here remark that this process has been of late years very extensively applied to forgings of all descriptions in which a repetition is constantly required of

the same outward form. Exact imitation of any desired pattern was only attained for many years by the process of casting, but these productions of the foundry being very brittle, were not suited for articles likely to be subjected to concussion. A piece of wrought iron, however, heated to whiteness, and placed between the dies of a stamping-press, is readily brought to the desired form without depriving the metal of its toughness and malleability, and the form can of course be repeated as often as may be desired. The value of such an application of the stamping-press is therefore beyond calculation, owing to the innumerable articles in everyday use which demand the repetition of the same form, unaccompanied by the defects inseparable from cast iron.

CHAPTER XV.

MACHINES FOR CUTTING AND SHAPING WOOD.

IN addition to the innumerable articles made of metal, there are a large number formed of wood, and for the more speedy and economical preparation of this material machinery has of late years been extensively called into action. Metal and wood work must of necessity be to a certain extent mutually dependent on each other, and their manufacture has always gone on side by side, but of late the softer material has been gradually replaced by the harder, with more or less practical advantage. The old wooden walls of England, the raw material of which was that British oak of which we were so justly proud, and which well typified the hearts of oak of our brave seamen, have to a great extent disappeared. The splendid frigates with which our many glorious victories were won no longer

ride in triumph upon the ocean wave. They have given place to those unwieldy-looking ironclads which have on more than one occasion earned but too justly the significant name of "iron coffins," and whose outline will never bear comparison with the graceful form of the old wooden ships that sat or sailed so proudly upon the waters. Nevertheless, it must be confessed that ironclad and heavily-armoured ships have become a sad necessity, owing to the extraordinary power of the guns against which they must henceforth be matched. The mass of iron which, with these guns, can be readily and *accurately* sent against a ship from the distance of a mile—guns which, with less accuracy, will hurl a heavy shot three times that distance, has rendered wooden ships utterly useless, and altogether modified the details of warfare. And if we turn from vessels of war to vessels of peace, we recognise also here a similar change from wood to metal; and in our various public buildings, and notably our railway stations in large cities, we cannot fail to notice the displacement of wooden roofs by lighter and more durable structures of iron and glass. Nevertheless, wood can never be wholly replaced by metal, and although iron beams may take the place of wooden ones even in private houses, we should hardly be contented to give up our wooden floors in favour of the more durable material. Hence wood must of necessity occupy an important place, and will always

be extensively applied to those manifold uses for which it is so beautifully adapted; and machines for the speedy and accurate conversion of this raw material are every year coming into more general use. To begin with that well-known implement, the saw,—how slowly, and with what vast amount of monotonous labour it is made to take its course through the timber which has to be cut into planks and boards! Even the honour of being top sawyer can hardly recompense the workman for the unremitting exertion he is called upon to exercise in the prosecution of his task; and as to him who is below, with the sawdust threatening to blind him, and the end of the saw taking its course in dangerous proximity to his body, *his* place can scarcely be described as an enviable one. Yet for centuries all the timber needed for the various purposes of trade had to be reduced by these means to the required form. But before the inventors of the steam-engine had given an impulse to our manufacturing industries, such as was never previously felt, a machine had been invented and extensively used to take the sawyer's place—the motive power being generally a stream of water, but sometimes a windmill. The arrangement was very simple, and by no means difficult to carry out practically.

A number of saw-blades, placed side by side at such distance apart as equals the proposed thickness of the planks, are fitted to a cross bar at each end, these cross

bars being also united by side pieces so as to make up a rectangular frame. This frame is constructed to slide up and down vertically within an outer frame; the up-and-down motion being imparted to it by a crank, to which either the top or bottom cross bar is attached. The axle of this crank is also that of the flywheel of the engine from which the motive power is obtained. The saw-blades can be arranged at any desired width apart by means of wedges or screws. The timber to be sawn rests upon a series of horizontal rollers in front of these saws, and motion is given to these by the engine, so that, as the work proceeds, the log of wood is gradually advanced. It is evident that whereas a single blade passing once through the timber would only divide it into two parts, a *single* passage of this many-bladed instrument will cut a number of planks; and so perfect is the action of the machine, that it may be almost left alone to do its work without attention. One man can at all events attend to several such machines. In a similar way, a very much narrower set of blades, arranged at a greater distance asunder, can be readily made to describe a curved path, such as is required for cutting out wheel-felloes, chair-backs, and any other articles of curved pattern. An automatic feed is, in this case, not so easy to arrange, and more attention to such labour-saving machines becomes necessary.

The inconvenience in certain cases of the reciprocating or up-and-down movement of the saw-blade, with the loss of time incurred in the up stroke, led to the invention of the band-saw, which has come into extensive use in cutting out articles of complicated form. In this case, a long thin blade is joined together at the ends, so as to make one continuous band, the junction being so beautifully made as not to increase at that point the general thickness of the blade. The endless web thus formed is strained quite tight by being passed over two large pulleys, one of which is placed at some distance above, and the other below the platform upon which the material to be sawn is laid. In this platform is a slit through which the blade passes, and the teeth point downwards, so that the cut shall be in that direction and tend to keep the work down upon the platform as the operation proceeds. The workman has the pattern into which he desires to form the material plainly marked upon its upper surface, and with the hands he keeps turning it about so that the saw may trace the lines accurately. It requires a little practice to do this, as a very little undue pressure will give the saw a bias in the wrong direction, and there is then no remedy for the false cut that has been made. With care and practice, however, very complicated forms are thus produced; and the ornamental letters seen on shop fronts, 2 or more inches

thick, are frequently made in this way. The cutting being continuous, no time is lost, and the execution of such work is of course very rapid indeed. Many of these band-saws, moreover, are made of hard steel, and are employed not only upon wood but also upon brass, which can be cut in this manner almost as expeditiously as the softer material.

In cutting smaller timber in any case where curved work is not required, the circular saw has come into general use, as its work is rapid and very true. It has also this advantage over the vertical sawing-machines, that it is easily arranged as a portable one, there being only needed a platform of iron, similar to a table, on which to fix it, and a farm engine as the motive power. These machines can therefore be hired out at any time, and are largely used to slit fir timber for making railway and farm fences.

A circular saw is merely a round plate of steel, the circumference of which is cut into teeth similar to those of a pit-saw if for large work, or of a hand-saw if only to be used on light material. In the centre of the plate is a hole through which is passed an axle, and which also carries the pulleys or riggers for a strap from the fly-wheel of the engine. The axle is fitted to work in bearings below the saw-table, and a slit is made in the latter to allow about one-third of the saw to stand above it.

The timber is laid upon a frame upon rollers, the end resting upon the surface of the table, and it is fed up to the saw by hand.

At one side of the table stands up an adjustable fence or guide, which can be set at any required distance from the saw, to regulate the thickness of the boards or rails to be cut; and as soon as one face of the timber has been trued, by having its uneven parts removed, it becomes a guide to the next cut, as it is pressed against the fence while the work is being driven forward. The saw is made to revolve with great rapidity, and the operation is a noisy one, but it is a very efficient and economical method of converting small timber. But the circular saw is not confined to the work of slitting timber, but is used as a very rapid means of cutting grooves, rebates, tenons, and other forms. The slate-frames, of which such vast numbers are now required to meet the demands of our many schools, are all cut out with this instrument, and the groove also for the slate itself is similarly made. It is evident that if the saw is only made to project a very little above the surface of the table, and a piece of plank is run across it, the latter will not be divided wholly, but only cut from end to end with a longitudinal groove, and that the width of such groove will depend on the thickness of the saw. Moreover, two or more saws can be mounted on the same axle, each doing its own special work, so that many such

grooves can be cut at once, or several strips cut at the same time. And it is also easy to understand that if a thicker circular plate be taken and the edge turned to any required shape—bevelled on one side or both, or rounded, or cut into the shape of a moulding, and teeth be cut round it—it will cut grooves of similar section in wood or metal, or reproduce such moulding.

It is by circular cutters of this nature that mouldings are now made in vast quantities for the use of carpenters and builders, instead of being made by a moulding-plane—a tedious and somewhat costly process. These circular cutters, whether for metal or wood, are often used in the lathe to plough grooves of given form, such as the V grooves needed for the slides of eccentric chucks, which it is very much more difficult to form with the file. Sometimes the cutter is fixed in a suitable holder in the slide rest, and driven from the "overhead," while the work is between centres or mounted on the chuck or face plate; and sometimes this mode is reversed, the work being clamped to the slide rest, and the cutters fixed in the mandrel. In a similar way stone is now sawn into slabs by circular saws without teeth, but fed by sharp sand and water, superseding, in a great measure, the old process of sawing by hand; but our readers will readily perceive that when very large saws become necessary, as they are for work of considerable diameter, the power required

to drive them is very great, and as no more than about one-third of the saw-plate can be employed, owing to the interference of the axle, vertical saws are more suitable for heavy and massive work, whether of wood or stone. The circular saw, nevertheless, is of such extensive use in works in which various articles of wood are manufactured on a large scale, that it now seems strange that we could have ever done without it; and its use, from the rapidity with which, by its means, wood can be cut up into the forms most suitable for the further operations of the carpenter and joiner, is invariable in all parts of the civilised world. By far the greater number of wood-working machines have reached us from America, which is a veritable land of timber, though Sweden and Norway rival it in its pine forests, and supply us with vast quantities of wood of that particular kind; and since the first Great Exhibition, in which nearly all the carpenter's work was executed by machinery, the prejudice against this mode of work has passed away, and all kinds of joinery, such as window-sashes, doors, staircases, and handrailing, can be bought at the manufactories, where large quantities of the usual standard sizes are kept in stock. Of course these are far cheaper than hand-made work, though frequently not quite so cleanly finished off. For green-houses, garden frames, fowl and pheasant houses, aviaries,

and similar outdoor buildings, few persons would now fall back upon the village carpenter.

Among the many appliances by which timber is converted, the wood-planing machine must here be noticed, as coming in order next to the machine-saw. Here again the work is performed by revolving cutters, which are not very dissimilar from the knives of some kinds of chaff-cutters, or of the lawn-mowers now so common. Steel blades with sharp-cutting edges are arranged round a cylinder or cylindrical frame, which is made to revolve with great rapidity, and the plank or board is made to pass evenly below it, being laid for this purpose upon a long level table of iron, and carried forward by gripping rollers. The whole is generally contained in a glass case, to prevent the shavings from flying about, as they are thrown off from the work in a perfect cloud. One great advantage of machine-work is the exact truth with which planks or timbers are worked squarely—the sides and faces at right angles to each other—this squaring up of carpenter's stuff being the very *pons asinorum* of aspiring amateurs and carpenters' apprentices, and being a work always of labour and difficulty even to more experienced workmen. The planing-machines remove this difficulty at once; for while each of the broad surfaces of boards are thereby planed, and faced parallel and true to each other, rendering the thickness equal everywhere, cutters arranged

for that purpose square up the edges at the same time. Nevertheless, if the latter are required to make any smaller or greater angle with the sides, or to be bevelled, these side cutters are able, by a simple arrangement, to be placed at the necessary inclination, and the required result is obtained with ease and exactness. By far the greater proportion of machine-work, therefore, as our readers will observe, is now done by *revolving* cutters of various kinds, and as a general rule these are stationary, and the work is made to traverse in the required direction. The advantage of a revolving cutter is that the action is continuous, thereby evidently saving time. When a carpenter saws or planes, the back stroke of the tool is of course thrown away, while with a circular saw or revolving plane there is no such back action. Time saved, it must be remembered, means cheaper production, as well as increase of quantity—both matters of very considerable importance when all classes of the community have to be provided with at least the necessaries of life. Reciprocating action is nevertheless in many cases a matter of necessity, and we must not dismiss the subject in hand without making a few remarks upon fret-saws, which have found a place now in so many private houses, and which afford a means of amusement of a very interesting, because artistic, character. The arrangement of a fret-saw may be varied in many ways to suit the fancy of amateur or professional

workmen, but primarily it is a very simple matter to plan such a machine, and to make it sufficiently well to answer the required object. To convert the circular motion of a flywheel and axle into a rectilinear one is the first requirement, and the simplest and best known method is the crank with a connecting-rod or "pitman." This is the plan usually adopted, and is applied by straining the saw in a suitable frame, and attaching this frame to one end of such connecting-rod, or by omitting the frame, and tightening the saw-blade by connecting one end of it to a spring overhead of wood, steel, or vulcanised indiarubber, the blade being made to pass through a plate or saw-table upon which the wood to be sawn is placed.

As many of our readers are in possession of lathes, and others are well acquainted with this tool, we may as well illustrate this subject by a drawing (fig. 61) of a simple machine to be attached to the mandrel, and driven by the foot, and it is designed to be made entirely of wood, so as to be easily constructed by an amateur. The base of the machine A is a piece of board 2 inches thick, and should be of oak, ash, or beech. It is to be a little wider than the lathe-bed, and accurately planed to rest fairly upon it. Under it is to be screwed a wooden block, just fitting between the bearers or cheeks of the lathe-bed, so as to retain it always in one position. Its length may

be 12 or 14 inches. B is a view of the under side, C being the block, and E a square hole half an inch

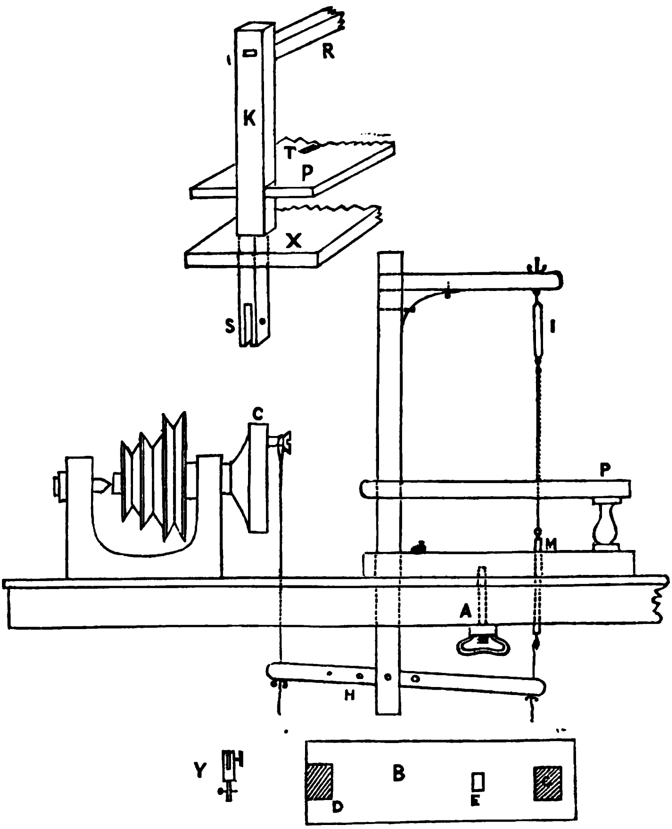

Fig. 61.—Fret-Saw.

each way, cut very cleanly at right angles to the face of the wood, and quite through it. At D is seen what

not only appears like a second block, but practically acts as such. It is, however, the end of the upright, which is here mortised into the base projecting below it, and slotted to receive the lever H, by means of which motion is communicated to the saw. To make this part quite clear the upright is shown again at K, and there will be noticed the main standard, the saw-platform P, the base X, the horizontal arm R, from which depends the indiarubber spring, the slit T through which the saw passes, and the slot S in the part of the standard which projects below the base to take the oscillating lever. The platform, of hard wood three-fourths thick, is notched out to fit the standard at one end, and is supported at the other by a couple of turned pillars, or by an upright standard of half-inch wood. In the profile of the machine A is the lathe-bed, and upon the mandrel is seen screwed a round disc of wood, an inch or so in thickness, into the face of which is inserted an ordinary wood screw. This acts as the crank or driver plate which actuates the machine, and converts the rotary movement of the mandrel into a reciprocating one. The further the screw is from the centre or axis of the disc, the longer will be the stroke of the saw; but this admits also of being varied by making several holes in the oscillating lever H. M is a squared bar of mahogany, or it may, if preferred, be of any other hard wood, or of metal, but a piece of Spanish

mahogany answers very well. At one end is screwed into it a small brass eyebolt, and at the other is cut a slit to receive the tail of a little brass clamp by which the saw is fastened. This clamp is easily filed up, and is shown at Y. The tail part is filed flat to fit into the slit in the mahogany bar, and there is a slot and screw by which to secure the saw. A similar clamp has to be attached to the lower end of the indiarubber spring, which is itself attached to the horizontal arm by such another eyebolt as fastens the strip of mahogany to the link uniting it to the lever below. This link may be of wire or of catgut. It is here represented as made of wire screwed to take a small hand-nut. The wire is passed through the arm, and by means of this nut the tension of the saw can be regulated. The object of the square bar is to prevent the saw from turning round upon its axis. In making this simple but really efficient fret-saw, care should be taken to give ample length to the horizontal arm and platform, or only very narrow work can be done, because in sawing fretwork the material has to be constantly turned about in all directions in order to follow the pattern, and if the distance between the saw and the standard is not of tolerably ample width, it is impossible to do this. If it should appear that the saw needs additional strain put upon it, as may sometimes be the case, the link connecting the screw on the crank-plate with the arm of the lever may

itself be a spring, and a bell-spring of coiled steel wire, purchasable at any ironmonger's, will be found to answer the purpose excellently. Its connection with the lever may be by a wire loop or link, of which the tail-piece may be screwed for a nut. Thus all parts can be regulated with the greatest nicety, and the saw kept tightly strained. This is very important, as otherwise it is sure to break. Although it is not our province here to do more than describe various machines and processes, we may add the remark that the material must be held down, and not suffered to rise as the saw ascends; and an india-rubber ball with a length of tubing should be so arranged that, by compression of the former, at each stroke of the saw the dust may be blown away from off the work, so as not to conceal for a moment the lines of the pattern.

Of course there are many other designs of fret-saws, and some of them are beautifully made in iron and brass with high finish and ornament, but the simple one here described will be found practically equal to any of these. In large manufactories, as, for instance, where fretwork is cut for the decoration of cottage pianofortes, the saws are worked by steam-power, and the platform is of large dimensions. The saws used make often 600 to 800 strokes a minute, so that an elaborate pattern is traced as rapidly as it could be delineated by pen or pencil. There is only one more saw that we need describe, and which is

by no means commonly seen, although for one special purpose it is of great service. This is the crown-saw—a steel band bent into a hoop, and brazed together like a band-saw, but very much wider and stiffer, and of small diameter. The teeth are formed upon the upper or lower edge, as may be most convenient, and the other is riveted to a circular plate, to the centre of the back of which a driving axle is attached with its riggers. This saw was invented for cutting out the round sheaves or movable pulleys of ships' blocks. It can, of course, only cut circular pieces all of one size, but this it does with great ease and rapidity.

We have said that no other machine-saw remained to be described, but there is yet one kind of circular saw of very large dimensions—so large that it cannot be made of a single plate, but requires to be built up in sections. One side is flat, the other is bevelled. The actual saw or cutting part is formed of segments of steel, which are riveted all round the edge of the cast-iron plate which forms the main body of the saw, and to the centre of one side of which the axle is fitted; for in this case the axle does not pass through, as in the smaller saws, but is attached to the convex side only, somewhat similar to the way in which the face plate is attached to the mandrel of a lathe. This is the saw used for cutting veneers, or those very thin boards of various handsome woods, which are glued down upon the cheaper sorts by

the operation called veneering. This is extensively used for all kinds of furniture. The log, squared up as truly as possible, is made to traverse across the flat side of the saw, being just near enough to detach a very thin slice, almost like a broad shaving. Being so thin, this is easily bent aside, and curls off on the bevelled or convex side of the saw, and is guided by upright rollers out of the way, in a path almost at right angles to that pursued by the timber itself. The thickness of each slice is regulated by a screw adjustment. Thin as such veneers are, there is a still thinner kind, which has been lately introduced to supply the place of wall-paper, and which is said to be as easy to hang as the latter. The object is to give to rooms the appearance of being panelled with oak, mahogany, or other wood of handsome appearance. We believe this is accomplished by a knife edge, and not by a saw—the principle being that of a plane; but we have not seen the work done, and cannot speak certainly upon the point.

BORING AND MORTISING MACHINES.

In addition to saws and circular cutters, such as planes, we require in large manufactories various machines for cutting holes in wood, both round and rectangular, and also machines for cutting tenons. Such as are made for cutting round holes go by the general name of boring-machines; the others are usually called mortising-machines. The

former are very similar to the drilling-machines, of which drawings have already been given in this volume; but the tools used are mostly of the character of screw-augers, which work easily and cleanly. Hard woods, however, require stronger tools, like the augers used by wheelwrights. These are made in sets of varying sizes, and fit into a spindle driven by steam-power. In some machines this spindle works vertically, in others horizontally; but in both cases there is a level table of iron on which to lay the work, and generally also clamps and guides to hold it, and to ensure its advance in a proper direction as the operation proceeds. With these any number of pieces can be bored exactly at the angle required and precisely alike, without any necessity for measuring and marking each individual piece. In the Great Exhibition building these machines were used to a greater extent than they had ever been before. The sash bars required to have gimlet holes made for the reception of the nails, all at precisely the same distance from the ends of the bars, and to effect this surely and rapidly there were long benches arranged, or platforms like very long tables, upon which were a row of horizontal borers or gimlets revolving at great speed, and projecting horizontally towards the lads or men who attended to the work. An upright light framework behind allowed the long rails to rest against them in a sloping position, while the other end rested on the table.

The gimlets thus made the requisite holes in them at a certain fixed angle, and all were bored exactly alike. This is merely an instance of the immense advantage of machinery over hand labour in cases where *a very great number* of articles are required of one exact pattern. It would not generally answer the purpose of a carpenter to use such machines, because his work is of so varied a nature. In all manufactories the case is different. Thousands or even tens of thousands of pieces of boards may be required exactly alike in size and shape, and with holes in the same relative position, and these could neither be produced fast enough nor cheaply enough, unless they were shaped and bored by machinery. The result, too, of its introduction has been the possibility of increasing not only the necessaries but the comforts and luxuries of life, and enabling the middle and poorer classes to obtain what before was only to be had by people of large means. Orchard-houses, for instance, greenhouses, garden frames, and vineries of all sizes, are now everyday affairs, and by no means unknown in cottage allotments; and articles of household furniture are likewise by the same means so cheapened, that what at one time was a luxury only for the few, has become the possession of the many. Not many years ago I remember seeing no less than 3000 wheelbarrows lying ready for shipment, all precisely alike, the frame only of the bottom being in each case

put together, but the sides and ends merely sawn out, and bored where necessary. The whole could be put together with no possibility of difficulty or chance of error, and the entire 3000 had been so far constructed in the course of a few days. In the same way, by the application of machinery, a close railway truck was made within twelve hours, to show the possibility of so doing. The iron-work was cast, forged, turned, and shaped; the timber sawn, planed, shaped, bored, and fitted; and the whole put together, every bolt and nut and screw in its place, within the prescribed period. With equal rapidity and exactness of workmanship the gun-carriages and ammunition-carriages are made in time of war.

Mortising-machines are chisels fitting into a socket in an upright or vertical frame, so as to rise and fall only in a perpendicular direction. The upward and downward movement is frequently effected merely by a long arm or hand lever in a very simple manner. Imagine a lever, for instance, like a pump-handle, hinged at one end, and a chisel fixed to it near the fulcrum by a joint—this chisel moving in guides to keep it upright—add a table below on which to rest the wood, and you have at once the main part of a mortising-machine. But in addition to the above would be required for practical use a clamp to hold the work, and also some kind of feed motion to shift it forward little by little between each stroke of the chisel,

or the latter would always descend on the same spot, and not cut a mortise.

This is managed by attaching to the vice or clamp which holds the wood a finely-cut screw, which in self-acting machines is turned by automatic gearing, a very little at each stroke, thus causing a slow movement of the material in a right line across the table. There is not always a feed action in the contrary direction, but the socket which carries the chisel is round, and can be turned at right angles to its former position, being retained there by a stop, after having been turned by a short hand-lever. In some machines, however, the reversing action is contrived by giving the table a movement upon a central vertical axis, which places the vice in any desired position, and of course the wood also. Thus, by simple means, mortises can be cut which are not rectangular, and may also be arranged radically around a common centre. Instead of the long hand-lever to pull down the chisel at each stroke, the latter is sometimes acted on by an eccentric cam like that used in the machines for punching and shearing iron, already described and illustrated. There is only the necessity here again of converting circular motion into rectilineal, different methods of effecting which we have alluded to before.

Among wood-working machines are also those of

American invention for tenoning and dovetailing. The former consists essentially of two circular saws at the exact distance apart to give the proper thickness to the tenon, the parallel sides of which are thus both cut at the same time, and the cheek pieces are then cut off by a single circular saw. The latter alone is quite sufficient to diminish labour in cutting a tenon, but the latter then needs to be marked out by a gauge, as it is marked for hand-saw work, whereas by self-acting machinery and permanent stops or guides there is no need thus to measure at all. The dovetailing-machine is far too complicated to be explained without more drawings than we have space or opportunity to give here, but the principle of it consists in setting pairs of circular saws at an angle to each other upon separate spindles, so that the cuts tend to a common point. This machine has not come into anything like general use, and is of course of very limited application. A good deal of work is now done by means of shaping-machines used with a dummy pattern of iron, and revolving cutters, acting simultaneously upon the various parts to be worked. Imagine, for instance, an axe-handle of the usual crooked form, made of cast iron, and pivoted at each end on centre points, so that it could turn round and round as if it were fixed on an ordinary lathe. This revolving motion is given to it, and there is a slide rest with a to-and-fro

motion, capable of being imparted to the tool-holder by means of a tail-piece or rubber which comes against the iron handle. Thus, as the latter revolves, it makes the tool go in and out according to its own shape, while at the same time the tool-holder is carried lengthwise, from end to end of the machine. A bar of wood which is to be made into an axe-handle is also centred at each end, and made to rotate against the tool, so that as the latter advances or recedes, it cuts shallower or deeper according to the shape of the iron pattern handle which regulates its movements. The tool is not, however, a fixed but revolving one—in short, a set of gouges fixed round a circular block of cast iron, to which rapid rotation is given, and which cut more cleanly than a fixed tool. This machine is called a pattern or spoke lathe, because wheel-spokes are now so made in great quantities for agricultural implements and carriages. It is curious to watch one of these, owing to the peculiar restless variety of its motions; but the work is done very quickly, and needs only to be cleaned off a little to render it quite equal to the best hand-work.

There are none of these machines except the fret-saw at all suitable for amateurs; but to those who have a lathe, the circular saw, up to about 6 inches diameter, presents a great many advantages. It is very easily mounted upon

a spindle to run between the lathe centres, and a very nice platform can be bought of planed iron for fifteen shillings, with a slot for the saw, and a parallel guide complete.

In the construction of any light articles in which the material does not exceed half an inch in thickness, the saw can be driven by the foot with no greater exertion than is requisite for ordinary turning of wood; but for material of an inch and upwards a good deal of power is required to drive the saw, and the work may be good for exercise, but is decidedly too laborious to be pleasant, especially if it is to be long continued. Circular saws are priced at so much per inch of their diameter. One suitable for a 5-inch centre lathe—say 6 inches diameter—would cost from three to five shillings, and may be had second-hand very often for half that price, spindle and all complete.

We need not say more of the few other wood-working machines, as they are after all little else than sawing and planing machines, modified in their details to suit them for particular operations. Grooving and tonguing as needed for floor-boards, mitring for picture-frames and similar articles, and various other modes of preparing work for joints, either at right angles or otherwise, are at last but modifications of the usual saw and chisel work

of the carpenter performed by mechanical means, and machines called universal joiners are chiefly the combination upon one frame or stand of the boring, sawing, and tenoning apparatus already described.

CHAPTER XVI.

PAPER-MAKING MACHINES, ETC.

IT is probable that not a few of our boys who have toiled over the rudimentary difficulties of writing have almost wished that copy-books had never been invented, yet perhaps they have wondered how the paper is made of which the said copy-books are composed. And those boys who have passed through, and now almost forgotten, the mysteries of pot-hooks and hangers, and have dug and delved in the mines of classic lore, know all about the wax tablet and stylus with which the writers of old days had to be contented, or the papyrus rolls of Egypt, the tree bark, metal, and stone which served as a medium of recording passing events, and handing down for future generations the interesting history of occurrences which must otherwise have remained unknown. Even the sand upon the sea-

shore has served as a slate on which to trace the mysteries of Euclid's *pons asinorum*, and many interesting problems were no doubt worked on that fickle tablet, to be erased and blotted out for ever by the returning wave.

Terribly laborious must the work of the scribe have been in ancient days for want of a better material on which to write, and many, no doubt, were the experiments made from age to age to find a material to replace the various defective substitutes for paper then in use. Of these the most convenient and most durable were skins, prepared like our parchment and vellum, to receive and retain the writing with more or less probability of standing the wear and tear of use, or the destructive effects of atmospheric changes. But those who have had to write on this material know that, however well prepared, it is not pleasant to use, and that its natural greasiness, which hinders it from taking the ink properly, is never completely overcome. Its chief value as a writing material consists in its indestructibility, which of course renders it of the greatest possible service in legal deeds, wills, and suchlike, and public records which it is desirable to preserve uninjured, it may be, for many generations. But for general purposes we should hardly be satisfied with this material; and we can assure our boys that if no better substance for our work had been invented, these books for boys would not have seen the

light. Yet whilst we write we can almost hear the sarcastic remark made, that in such case there would also have been a blessed dearth of Latin grammars and similar unlovable abominations, making it a questionable fact in the schoolboy mind, whether, after all, the blessings of the invention of writing-paper are equal to the evils thereof. Well, well, youngsters, time will modify even the difficulties of that question, and we may remind you that after the schoolboy and satchel all are past, Shakespeare has a word to say of another age, in which certain sonnets to young ladies' eyebrows demand the whereon and wherewithal to write, and possibly when that age of sighs has arrived, the true value of paper "cream laid" may begin to be appreciated. To the scholarly boy, with the "Balliol" or other prize in view, the question presents an altogether different aspect; and if *he* has any regrets upon the subject, they are simply that paper was not invented and profusely used ages before it was actually known.

To begin at the beginning we must go back for awhile from amongst machines to a period of paper-making by hand, which dates from a very early age, and comes down almost or quite to the present century. Indeed there is "hand-wove" paper to be had even now, and for certain purposes it appears to find special favour, though the quantity so produced has long proved utterly inadequate

to meet the demand of modern times. Animal matters occupy, we believe, absolutely *no* place in the manufacture, vegetable fibrous substances being alone found suitable. These require to have a certain natural degree of toughness; and although experiments have been made with substances which are deficient in this quality, they have not proved altogether satisfactory, as the resulting paper is too easily torn to be of sufficient durability. But for some of our daily newspapers, and similar publications, which are not generally required to last beyond a very limited period, paper made of straw and other naturally brittle substances is found to answer sufficiently well, and being cheap, is sure to meet with a satisfactory market. Probably further research may be rewarded by the discovery of a far greater quantity of available material in the vegetable world. Nettles, for instance, furnish a fibre of great toughness; and if this and certain other plants of similar character were not imbued with a colouring matter difficult to bleach to perfect whiteness, there is little doubt that it would be used to a great extent in this important manufacture. At present the material most in demand is linen and cotton rag, collected, as is well known, by the rag-and-bone merchants from every cottage and mansion in the kingdom. These consist of hempen, cotton, or linen fibre, silk and wool belonging to the animal kingdom, and being useless for

the required purpose. We hardly like to comment upon the condition of this raw material as it enters the sack or donkey-cart of the rag-collector—it is simply a state of unmitigated and apparently hopeless dirt; yet when it next appears in public it may be upon the writing-table of royalty, in the form of the fairest and most spotless notepaper, embossed with the royal arms and commanding a royal price—or perhaps it attains to yet higher dignity, and having been converted into paper of a peculiar crisp and altogether pleasant though flimsy quality, and stamped with certain mysterious figures and emblems, takes a very important place in the wealth of nations, and is worth at least a million times its weight of solid gold.

The three substances mentioned above as the raw material of rags possess qualities rendering them admirably adapted to the requirements of the papermaker. The fibres are easily separated from the surrounding parts, and are tough, procurable in great quantity, and easily bleached. Of these qualities the cotton-spinners and manufacturers of woven goods take advantage first of all; and when the productions of the loom are no longer capable of the use originally intended, they descend by rapid steps from the wardrobe to the kitchen, thence probably to the beggar, and often even to the dust-bin, from which being rescued by the rag-picker and

ragamuffin, they find their way to the sheds of the paper-makers.

The first work, and by no means a pleasant one, is to separate the heap of rags into the various qualities of which it is sure to consist. This is sometimes, but not invariably, done by the rag merchants, who purchase from the collectors, and of whom many make large fortunes by patient energy and toil in this uninviting sphere of labour. The finest linen rags are set aside for the manufacture of the highest qualities of writing-paper. The cotton rags make paper suitable for the printer, while hempen rags come in for a place as constituents of paper of coarser qualities, as brown, whity-brown, and household paper of various denominations. But as may be supposed, there are many intermediate qualities to be obtained by a judicious combination of two or more of these materials, which are also adulterated by the addition of straw and certain grasses, cotton waste from the loom, and various odds and ends which alone would be utterly unsuitable, but thus combined are made to lend their aid in the manufacture. It is by such admixtures and combinations that the manifold qualities of paper with which we are familiar are produced, the smooth or rough surface depending partly on the nature of these combinations of raw material, and partly upon special details of manufacture. In some we see a number of

equidistant lines running up and down or across the surface; in others these are not apparent. Some are to a great extent absorbent, as filtering and blotting paper; others so highly polished as to receive ink with difficulty, and hence we meet with such terms as "absorbent," "blotting," "hot-pressed," "laid," "roan," and similar technical names by which manufacturers have agreed to designate the various qualities sold. Some or all of these terms we shall be called on to explain as we pursue our description of the art of paper-making.

The rags having been duly sorted, are first of all freed from mere dust; but some of this is removed during the sorting process, the rags being placed on coarse wire frames, which form sieves through which a good deal of the coarser dust and dirt falls as they are tossed over by the sorters and pickers. This wire-covered table is called by the technical name of a "Lettice," probably a corruption of the well-known name Lattice. This, however, only removes the *loose* dirt, which forms but a small portion of the multifarious defilements which remain upon the rags under the operation. But the next process is to place them in the "willowing"-machine, the origin of the name being unknown to me. This consists of a large cylinder set with teeth, which, revolving at a very great speed close to a concave board also set with teeth, tears the rags at once into fragments,

during which process a great quantity of dirt separates, and is got rid of by the falling of the torn fragments on a sieve. From this machine the rags are carried to another for final *dry* cleansing. This is a revolving sieve, of which one end being fixed at a higher level than the other, the rags have a constant tendency to fall towards, and finally drop out of, the lower end, which is open. This sieve has a sidelong motion as well as a circular one, being shaken all the time from side to side for the more effectual disintegration of the particles of dirt and dust. This is all that can be done by the dry process alone towards complete cleansing of the rags; but as yet they are of course far from clean, and are now subjected to the process of boiling. This is conducted in boilers which are made to revolve during the operation, and into which steam at a high pressure can also be admitted, which keeps the contents of the boilers in a state of constant agitation, and drives the boiling fluid with great force among the rags and other materials. A quantity of soda-ash or caustic soda is for this washing added to the water, in order to get rid of grease and other impurities, which it does very effectually.

After the rags are removed from the hot-water boilers, they are placed in washing-pans, where they are subjected to thorough rinsing and agitation in clean cold water, which removes all trace of the soda-ash. These washing-

pans or washing-cylinders are not only made to receive and rinse, but also to further cut and subdivide the rags by a series of knives within them, and the rags are driven against them by the rush of water, which, by a complicated arrangement, is made to take place with great violence, so that the rags, now fast becoming pulp, are dashed and driven again and again against these sharp cutters, until thorough disintegration of every part has taken place, and a uniform fibrous, pulpy mass is produced. This now has to be bleached with chloride of lime, and is coloured or not as may be desired with various well-known earths or mineral colours. The pulp has at this stage no consistency. It is evidently full of fibre, but so wholly disintegrated by the processes which it has undergone, as to have apparently no cohesive property. But if a portion of pulp is now lifted on a strainer or sieve of any kind, so as to allow the water to drain off, it will become at once felted together and consolidated, and is, in point of fact, unsized paper. Formerly the sheets were wholly made by hand in this way. A wire deckle was taken, which was a square of fine wire gauze with a very shallow frame resting on it of the thickness of the sheet of paper, and with this a workman dipped up a portion of pulp from an open vat, shaking the deckle from side to side as it was raised, to get rid of the liquor and cause the felting of the pulp. In the coarse old

papers the wires of the deckle are very plainly impressed, giving a very rough surface, which, strangely enough, is again coming into fashion, but is to our mind anything but agreeable to write upon, and must always have been terribly destructive to the point of the pen while the latter was made from quills, and so far as we can say from a brief experience, equally unsatisfactory with steel pens, the points of which, if not broader than usual, are liable to stick and hitch in the unequal surface of the paper. With finer wires or webbing, in which the threads of metal are made to run across as well as lengthwise, to form a closer and more compact web, the marks made by them in the paper are much less conspicuous. This paper is called by the name of "wove;" the other is designated "laid," being blue-laid or cream-laid according to tint. The laid papers, although they still show plainly the marks of the wire of the deckle, are now made with a beautiful surface, sometimes very highly glazed, sometimes less so, according to the demand for rough or smooth. Similarly, the wove papers may be had variously finished to suit the fancy.

We have already stated that hand-made paper is still in great demand for various purposes, especially for water-colour painting, but by far the greater quantity in the market is wholly made by machinery, the principle of which is identical with that just described. But in order

to provide this material in sheets of any required length, as required in wall-papers for decoration, it was seen by manufacturers that the hand-deckle must be superseded by some kind of continuous web, and as the art of weaving fine wire into netting and webbing became perfected, it was an easy matter to form such a medium into a continuous or endless band of any desired width. Such an endless band passing over rollers at each end, to which motion is imparted by the steam-engine or water-wheel, is fitted just in front of the vat in which the pulp is contained, and this is caused to flow out in a regular broad but thin stream or layer upon the wire, which is at the same time given a shaking motion in imitation of that imparted by hand to the deckle, and for the same purpose of shaking out the water, and causing the felting and consolidation of the pulp. By this travelling belt of webbing the paper is carried forward from the vat in an endless sheet, and made to pass under rollers placed at intervals in its course, which by the pressure they impart consolidate and dry the pulp more and more in its passage, until it assumes the necessary consistency, and is wound as a continuous sheet upon a roller at the further end of the machine, which looks somewhat like a long table fitted up as a series of mangles, or as some kind of washing and wringing machine. We have said that in its course from the vat the pulp passes under and over

certain rollers; one is called a dandy-roll, and the lines on laid paper which is machine made are impressed by its means, this roller being of wire arranged to form any device which it may be desired to impress upon the sheet, and which is well known as the water-mark. This is frequently the private mark or the name of the manufacturer. In addition to this wire dandy-roll are cylinders heated by steam, over which the paper is carried on a felt web, to assist in drying it rapidly, pressure rollers of polished steel giving it a still further finish. We have omitted mention of one or two other details of the machine intended to secure its perfectly pure surface by assisting to remove any sand or dirt which the pulp may have brought with it, and which must be carefully strained off in order to produce the best qualities of paper. For the coarser kinds of brown paper this is less requisite, and on inspection of some of the kind known as sugar-paper, many bits of extraneous substances will be seen upon its surface and embedded in its texture. But these coarse unsized papers are just the kinds to give an insight into the nature of the manufacture, because in them is clearly seen the *felting* of the pulp, the crossing and interlacing of the fibres which give it consistence, and it is plain that no substance which has not this fibrous texture can be used alone, although it may be added in moderate quantity to materials which possess this quality without any serious

diminution of the tenacity of the paper produced. It is thus that straw, which is naturally brittle, owing to the abundance of silica which it contains, is made to serve the purpose of the paper manufacturer by admixture with the linen or cotton rags.

The paper thus made and dried needs to be sized to a greater or less extent, according to the purpose for which it is designed. In its unsized condition it is similar to blotting-paper, and ink or colour would run if used upon it. Size is prepared from the cuttings of leather and parchment from glovemakers, bookbinders, and others, which contain a quantity of the substance known as gelatine, which is similar to isinglass, but of a coarser quality. It is, in fact, a light kind of glue. The paper is drawn through a vat filled with this size, which is sometimes made to intervene between the drying cylinders, so as to complete the paper before it is wound upon the rolls, and sometimes is made a separate operation. In either case the paper, after passing through the vat, is pressed between rollers to squeeze out superfluous size, and dried by a current of air or by steam-heated cylinders, and very frequently is further smoothed and finished by passing finally between other polished rollers, to give extra gloss to the surface. A paper manufactory is a regular Turkish bath, always full of steam and heated air; for it is necessary to dry the paper completely in its passage

from one end of the machine to the other, and it is marvellous to see how rapidly this drying is effected by the means employed. At one end is the pulp in a perfectly fluid state, at the other is a roll of dry paper, rapidly increasing in bulk every minute, and ready to be delivered as a continuous sheet, or to be cut up as occasion may require into foolscap, notepaper, or other samples recognised as standard sizes by the retail dealers. Paper-mills used to be erected on the banks of streams and rivers, for the sake of obtaining water-power to drive the machinery, and were very picturesque and favourite subjects for the artist's brush. We remember one of this class at Iffley, near Oxford, which is now, I believe, burnt down; but steam has so effectually rivalled water-power, as to make locality a secondary object.

PRINTING-MACHINES.

What a terribly laborious, not to say tedious, operation writing is, we need hardly, perhaps, tell our boys who have struggled at the elements thereof, and idled over their exercises. And after the jacket has been exchanged for the much-coveted "tails," and the whiskers have become established facts, writing, though it may have become a comparatively easy work, is still at best a very slow and unsatisfactory way of recording one's

thoughts for the benefit or the vexation of possible readers. When a lad takes up a book, whether of adventure or of fiction, or of something of a drier and less interesting character, he seldom, in all probability, cares much about the labour expended upon it before it reached his hands. He knows nothing of the many hours of patient industry and thought which it cost the writer; the painful diligence and care required in setting up the type, letter by letter, especially if the manuscript were not of the most legible character, which it seldom is, in point of fact, as it is generally written more or less hurriedly, and the hand gets cramped and stiff after a lengthy spell with the pen. But if in addition to this, and the revising and re-revising of the proof sheets, the folding and stitching, and binding and packing are taken into consideration, it will be evident that the production of a book is by no means the simple matter that many suppose it to be.

But what a multiplication of all this toil would result if it were necessary to rewrite the whole for every additional copy required!—and yet at one time this was the sole method known of producing books. Before the art of printing was discovered, every volume was the work of the pen alone, and each copy required had to be produced by the labour of the professional scribe.

We read in the Prophecy of Jeremiah, and in some other

parts of the Bible, of the "roll of a book;" and the sacred law of the Jews, written upon such a roll, is, we believe, still in existence, if not in actual use in their synagogues. This roll was a long strip of parchment or paper, mounted at each end upon a wooden rod, upon either of which it could be coiled, so as to reduce it to a small compass, and preserve it from injury.

The word "volume" which we still use, being derived, as our boys will now at any rate guess, from the Latin word *volvo*, to roll, was applied to each of these, and they were usually numbered on the outside, and placed upright side by side in the several compartments of the public libraries, few persons in those days having a private supply of such volumes, owing to the cost of their production. But there were not many able to read, for there were no Elementary Education Acts in force in the villages, although in the later periods of these rolled-up volumes schools under the government superintendence began to arise in Greece and Rome, and were, very probably, also existent in those mysterious and ancient nations China and Japan, and perhaps in India also. It may also be mentioned here, in reference to educational matters, that Ireland, or the Sacred Isle, was a stronghold of learning centuries before England had any pretensions to be called a nation of arts and sciences. It is curious and very interesting to find the traces of civilisa-

tion in these countries which date back into some bygone ages, the very records of which are buried in oblivion—traces, and traces only, which hint at knowledge and a state of high culture subsequently lost, and only now tardily emerging again from the barbarism and ignorance which mysteriously overwhelmed it. But so it is, and it is more than probable that we are now painfully and laboriously recovering inventions and processes, and knowledge of various kinds, which in those bygone ages were universally known. But this subject opens out too wide a field for our investigation in these pages, and we only speak of it here with the chance of addressing the minds of some of our boys whose proclivities may tend in this direction, and in whom we may possibly kindle the spark of inquiry which may one day lead to valuable investigation and research. It appears, at any rate, certain that many nations have retrograded, and lost a great amount of knowledge which they once possessed. Of mechanical knowledge, for instance, we have standing evidence of this loss in the stones of those Druidical monuments like Stonehenge or Avebury, or the Egyptian pyramids and monoliths so interesting to the archæologist. Of the mode in which these huge stones were quarried, moved to their present site, and made to stand upright, not only does no reliable record exist, but it is questionable whether with our present knowledge of steam-

power and various mechanical appliances we could have accomplished the task.

But it is easy to understand how knowledge was lost in any age in which the arts of writing and printing were unknown. When even manuscript volumes were few, and when the material of which they were made was perishable, it is plain that there could be very little chance of their preservation; and although we have records in more durable material—viz., the inscriptions upon stone which have lately occupied so much of the attention of *savants*—the characters are difficult to read, owing to their long exposure to the elements, and when deciphered, are equally difficult to understand. Whatever of knowledge, therefore, existed in ancient times when these rude and unsatisfactory methods prevailed of recording it, our own rapid advance in civilisation must date back to the discovery of the art of printing and paper-making. From that time books have multiplied, and their cost has been reduced, until it has become a question whether such cheapness of production is the blessing which at first sight it may appear to be. Although it is an unquestionable blessing to be able to provide copies of the Holy Scriptures, and of many other good books, at a price which is almost nominal, this same cheapness introduces thousands of immoral and baneful publications, which have become a very curse to our nation; and it is sad to find in this, as

in other things, that wherever good is present, evil is sure to find a place at its side. However, we must not delay our special work in order to moralise, although it is difficult to speak of the arts of writing and printing without some allusion to their practical influence upon the world at large. So far as can be ascertained, the Chinese were the first in this, as in many other inventions of importance, and the first experiments were doubtless made with wooden blocks, upon the face of which letters and other devices were cut so as to stand in relief, these being then smeared with ink or colouring matter, and impressed upon the paper by hand. It is also by no means improbable that another mode was used which we now call stencilling, and which is of great use where a great number of copies of the same device need to be produced in colour upon the surface of walls, ceilings, paper, and various other substances. In this case thin plates of metal are pierced quite through with the intended device, and this is imprinted, not by pressure, but by holding the stencil-plate down upon the material, and rubbing the colour by means of a short-haired stiff brush on the space exposed by the plate. This process is extensively used in the arts, and is very likely as old as the inscriptions on Egyptian mummies. In fact, wherever we find *perfect* similarity of form repeated very frequently, there is good reason to think it was produced in this way.

Type-printing is, like wood-engraving, always from raised letters; copper-plate and steel engraving from lines cut into the surface by means of the graver. In the first the projecting parts receive the ink; in the latter it goes into the lines, and thence is transferred by pressure to the paper. The large letters seen in hand-bills are cut in wood blocks. The ordinary-sized type for printing books is formed upon the end of slips of a metal similar to zinc in appearance, called type-metal.

Printing was first discovered or invented by one Coster, at Haarlem, in Holland, in the year 1430, if we except the Chinese knowledge of the art, which, though claimed to have been centuries prior to Coster's, is of course not absolutely reliable as an historical fact. At the same time, the statements made by them may possibly be correct, for we know very little of the history of their arts and manufactures. Coster, however, did not print from movable types, but from wooden blocks on which the words were cut. This Coster, however, had an apprentice called Fust or Faustus, who one day ran off with his master's printing apparatus, and established an office of his own at Mentz. Movable types, upon which individual letters were separately cut, were the invention of Fust's own apprentice, Peter Schoeffer, and the letters were first of all cut in imitation of handwriting. But the Parisians who bought copies of the Bible, or of parts of it printed in

this way, soon saw that no writer could have made all so precisely similar, and with the superstitious feelings of the day, accused Fust of sorcery; and so this Dr. Faustus was supposed to be in league with the Evil Spirit, or to be in very truth the Evil Spirit himself. The result of this report was that Faustus was obliged to reveal his secret, and was compelled to make known the system of movable types, which laid the foundation of the art as it has ever since been practised. Very rapidly after this printing made headway throughout the whole of Europe, and by 1480 one book at least had been printed in England. At first no press was used to take off the impressions, and one side only of the sheet was printed, the operation being conducted entirely by hand. It was soon found necessary, however, to use greater power of pressure than the hand could supply, and the screw-press was consequently introduced; but for each impression required it was necessary to give several turns to the screw by means of the lever-handle, and this occupied more time than was convenient, and the screw had also to be turned several times in the contrary direction to raise the platen from the type. The screw, moreover, though it would supply the required power, did not exert it suddenly, and in the special way in which the clearness of the impression was most likely to be secured.

The first great improver of the press, however, Earl

Stanhope, did not discard the screw as a means of power, but by making it of a quick thread, he gave it the necessary rapidity of motion, while by the addition of a couple of levers the handle was brought closer to the operator, and the power was increased. This, moreover, was an iron press instead of the wooden ones hitherto used—a great improvement, not only in appearance, but also, which is of greater moment, in the accuracy attainable in the various parts, especially the accurate surface of the platen, and the table upon which the type was placed. Earl Stanhope, who gave his invention to the public, did a great deal by this means to advance the art of printing in England, and his press met with great favour at the hands of practical men. But, like most other inventions, this was supplanted in course of time by presses of greater power, notably by the Columbian and Albion presses, in which the arrangement of the working parts was greatly improved, and it became possible to print pages of greater size, as well as to obtain clear impressions of woodcuts. These last need an astonishing amount of pressure to bring out every line and mark clear and sharp, and hitherto success in this particular department had been but small. In all these presses the power depended either on the screw alone, or in combination with an arrangement of levers. One object aimed at in this was to reduce the distance through which the handle of the press required to be pulled by the workman;

another was to increase the power, and so arrange it that, instead of causing only a gradual and uniform descent of the platen, it should bring it down gently at first, and then suddenly increase the pressure of it on the types. This the screw cannot effect, and subsequently to the invention of the Columbian a press of great power was constructed somewhat upon the principle of the knee-joint. We know that in rising from a kneeling to an upright position we can, by the act of straightening the legs, raise a considerable weight resting upon the shoulders. The power thus exercised is but small when the knee is much bent, but increases as the leg becomes straighter. In the press made on this principle the joint is not quite so simple as a mere hinge in the centre of a bar, but the principle is the same—the rotation of a cam fixed to an upright shaft causing two short pins to rise from a slanting position into a vertical one, practically adding a little to the length of the shaft and so pushing down the platen, upon the upper surface of which the lower ends of the short pins rest. This is evidently only a modification of the knee or toggle joint before alluded to, and is a mechanical combination of great power. For many years no other means was devised for taking off the impression of the types. The latter were inked by means of two balls or stuffed cushions faced with leather, with short handles attached to the backs. These were

covered with printing ink by first smearing the latter upon a slab of stone, and rubbing the balls upon it, so as to distribute the composition evenly and thinly over the surface; the type, set up and securely clamped together in it: chase, so as to form one or more pages, was then struck with the balls until thoroughly inked; the forme was then run back under the platen to receive the pressure.

But perhaps it will be as well, whilst speaking of the hand-press, to enter a little more into details of its construction. We have hitherto been chiefly engaged with that part of its mechanism by which the pressure is imparted, and have said nothing about the way in which the paper to be printed is arranged and held. Travelling on a pair of horizontal bars or bearers, one end of which is under the screw or lever giving the required pressure, and the other on a pair of legs, is a travelling carriage, which is made to run to and fro at pleasure by a winch-handle, and a roller upon which the carriage rests. This is called the coffin, and in the earlier presses, which were made of wood, this was like a shallow tray, which was made to contain the large flat slab of stone or marble upon which the forme was placed after being damped in its frame or chase. This stone was, when iron presses were substituted for wooden ones, replaced by that metal, which was easily planed to a perfectly level surface. Attached to this coffin at one end by hinges is a frame of iron covered with a

blanket called a tympan, to the extremity of which is attached by a second pair of hinges another frame called the frisket, with adjustable bands or tapes stretched across it, which fall upon the margin of the paper and between the columns, and serve to keep them clean. The paper being placed upon the blanket of the tympan, the frisket is shut down upon it, and both are then turned over upon the forme of type, the latter having been inked by means of a roller of indiarubber or composition, which is first worked on the inking-slab. By means of the rounce, or winch-handle and roller, which moves the carriage to and fro, the whole is then run under the platen, and one pull of the handle by the pressman takes off an impression. The carriage or coffin is then run back, the tympan and frisket raised, and the printed sheet removed. About 300 impressions an hour can be struck off on a hand-press of this kind. The paper is always used damp, as it yields better in this condition to the types.

Such was, and is, except in large establishments, the machine by which the literature of all nations has from time to time been printed for many years. Presses of this kind were found quite sufficient for the work. But when newspapers and periodicals began to multiply and increase, and especially the "Times" newspaper, mechanical ingenuity was turned in this direction, in order to

discover a more rapid and effectual method of meeting the demands of the public. Even with plenty of hands at command, 500 sheets an hour was accomplished only with the greatest difficulty, and means were required of at least doubling or trebling that number.

The printing-machine which resulted from the labours of inventors, and of which the *principle* has ever since remained the same, although the details have been modified, consists of a series of rollers of large size mounted upon axles in appropriate frames fixed at the edge of a long table or frame across which the rollers lie in a horizontal direction. Over and under these the sheets to be printed are carried by means of tapes, which lie upon the margin and between the columns like the tapes of the frisket, and these served the same purpose of keeping the paper clean in the places where they fall, and also of conducting the sheets squarely and accurately upon their course. To make the action clear, we may suppose two such rollers only, parallel to each other at a short distance apart, and revolving in contrary directions, and that tapes pass over the first and then underneath the second, and that types are set in order upon each cylinder. If a piece of paper were laid on the types, and caused by their movement to travel onward, it would come in contact with the types, first on one side as it passed over the first cylinder, and then on the other as it passed over the second, taking

the impressions of the types on its passage. This was the plan first tried, the types being made smaller at one end than the other, or wedge-shaped, so that they should fit close to each other side by side when fixed upon the curved surface of the cylinders. The types were inked by revolving in contact with an inking-roller, against which they were brought just before the sheet of paper reached them. There being a difficulty found in setting the types evenly upon a curved surface, the next arrangement made was to fix them as usual in a chase, and to place the latter upon a level table or bed, which is moved to and fro by a rack-and-mangle movement under the cylinders, the speed of rotation of which is accurately adjusted to correspond with that of the type-table. The paper is fixed securely by clips upon the cylinder, so that it shall not be able to slip from its exact position. There was great difficulty experienced at first in communicating to the type just as much ink, and no more, as was needed to produce a satisfactory result. This was accomplished at last by causing a thin film of ink (which is about the consistence of treacle) to fall upon a roller of steel from the edge of a plate of steel upon which it is spread, which plate is accurately ground on the edge so that its distance from the roller can be accurately adjusted. From this distributing roller the ink is transferred to others, the surfaces of which are covered with an elastic composition

made of glue and treacle, and under two of these the forme of type passes backwards and forwards after each impression. There are two of these formes in action at the same time in the double machines of Cowper and others, at each end of the carriage. In fact, the double machine for printing both sides of the sheets at once is merely a pair of single machines, each part being in duplicate and alternately coming into action. It was considered excellent work at first to print 1000 sheets an hour on both sides, but even this vast increase over the work attainable by the hand-press was found insufficient. The more newspapers people got the more they wanted, and very soon by means of improved machines 3000 copies an hour were printed, and soon after this was increased to 4000 and 5000, which one would have supposed amply sufficient to meet every demand. Far from it: the public had an insatiable appetite for news of all kinds, and with a quadruple press, made for the proprietor of the "Echo" by Messrs. Marinoni & Co. of Paris, 20,000 copies of that paper, or any other, are produced with ease in an hour beautifully printed upon both sides. I believe I am right in stating as a recent modification of the printing-machine an arrangement for automatic supply of paper from a roll placed at one end, which delivers it in one continuous sheet. This is not only printed on both sides, but cut into single newspapers as it passes onward, saving the

original cost of dividing the paper before feeding it into the press.

Such is the steam printing-press as it is now made; and considering the rapidity of its action and accuracy of its various movements, we cease to wonder that literature of all kinds has so vastly increased of late years, while it is ever a cause of regret that the "liberty of the press," whereby it is freed from almost all State control, should ever be abused by the circulation of vicious works, disgraceful to the writers as well as the publishers, though unfortunately profitable to both.

TYPEFOUNDING AND STEREOTYPING.

This is not a work that is carried on "amongst machines," but is nevertheless so closely associated with our subject as to demand at least a brief notice in this place. Each letter and stop is separately cast in a mould divided vertically into two parts. When put together, these form a square or oblong channel down the centre the size of a letter, and as the channel is enlarged at the upper end to facilitate pouring the type-metal, it becomes funnel-shaped at the part, producing a similarly enlarged end to the letter or type cast in it. This is afterwards broken off, and the

end dressed by a kind of plane. A mould of this kind therefore will, it is evident, cast a rectangular slip of metal, but it will have no letter or device upon it. The same mould, however, is in a very ingenious way made to serve for casting different letters if their shanks are to be nearly of one size, for there is a little power of adjustmen also in this particular. Near the bottom of the double mould is a slot or channel, into which is slid a slip of copper called the matrix, on one side of which—the *upper* side when it is in place—is stamped by means of a punch the letter, or stop, or figure which is required. The letter is cut on the end of the punch, which is of steel, by suitable tools, and it is then hardened. It is afterwards laid on the slip of copper, and struck with a hammer, by which the letter is *indented* in the copper. When the metal, therefore, is poured into the mould, it takes the form of this indented letter, which stands up in relief upon its end, and only needs a very slight dressing to make it sharp and clear, forming a type for printing. Thus, as any one of these copper matrices will slip into the groove in the mould, the latter will serve to cast any letter that may be required of one size. Of course some letters are wider than others, requiring a broader type; but for these the mould is adjustable to a certain extent, as the two halves of which it is composed will slide sideways on each other, increas

ing in one direction, but not in the other, in the thickness of the type.

We have nothing to do in these pages with the actual work of printing, our object in these books for boys being rather to give the latter a taste for scientific and mechanical research, and to give them a good "notion" of how the manufactures and industries of our great country are carried on. We wish them, therefore, having gained from these pages some insight into machines, to go and inspect them for themselves, and thus perfect their knowledge. A visit of an hour to a printing-office will do more to give them a knowledge of the work than a hundred additional pages of our present book; but the latter will prepare them for what they are about to see, and render everything which they will meet with more easy of comprehension. We must, however, add a few words about stereotype work, because this has done so much to multiply and cheapen all classes of literature, and the process is not difficult to understand or describe.

Supposing that it is wished to preserve a book in type, so that other editions may at any time be printed in all parts like the first, it is easy to perceive the cost of having all the millions of letters locked up and useless while the first edition is being sold. The forme therefore, *i.e.*, the frame of type sufficing to print a sheet, which may be two,

four, eight, or more pages of the book itself, is laid face upwards in a kind of square shallow box or tray, and plaster-of-Paris is poured on the face of the type previously oiled. When dry and set this is removed, and made a mould on which to cast a plate of type-metal similar to that of the single letters themselves. If this operation is carefully carried out, the result will be a solid plate of type precisely similar to that set up in the chase, and affording in the press just as good an impression as the original. These stereotype plates are not cast, however, as thick as the length of a single type, and would not stand the requisite pressure by themselves. They are therefore backed with wood to bring them to the required thickness. A large number of such plates must lie stored to make up a whole volume of any size; but the expense is comparatively small, as, when done with, they are broken up to be recast when required. Another plan of making stereotype plates, without using plaster-of-Paris, is by fixing the types as before in the chase, and striking them suddenly, face downwards, into a tray of semifluid type-metal, just as a seal is struck into melted wax, only for this a special apparatus is needed to hold up the chase until the proper moment, and then, just as the semifluid type-metal is on the point of setting, to dash it vertically down upon it. The impression thus made, in what is in a few moments a solid block of metal, serves to take the place

of the original, and is struck in a similar manner into a second tray of semifluid metal. The latter now consists of raised letters fit to be used in the press. Very sharp impressions are taken in this ingenious manner, but the mould must be struck at just the proper moment.

CHAPTER XVII.

GLASS-MAKING.

AMONG the various things made and used every day, there are few more interesting in their manufacture than articles made of glass; yet it is not every boy—no, nor every boy's parents—who has the slightest idea of the processes carried on in glass-works. Bottles and glasses of every form are taken in hand to be used or broken as the case may be, and curiosity is not roused as to how they were manufactured: all that *is* known is that all such articles are extremely brittle, much given to come to grief, and not so wonderfully cheap as to make breakage an inconsiderable item in the family outlay.

Probably most of us are acquainted with the old story of the accidental discovery of this valuable material by some Phœnicians, who, being shipwrecked on the coast

of Tyre, where the plant kali grew abundantly, noticed that the ashes of this plant, combining with the sand under the heat of the fire used for cooking, fused into the substance now called glass. At all events the material was known to ancient Egypt, and certainly mentioned three hundred years before the time of Christ. Like many other things now well known to us, the real origin of glass-making is buried in obscurity. No doubt, however, can be entertained that, if the story above named is true, the glass produced was a comparatively opaque body, apparently little likely to become of extensive use where perfect transparency might be needed. Nevertheless this union of sand and kali through the agency of heat is veritable glass, although the mode of preparing it now adopted is somewhat different.

It is now a very long time since the days of unglazed windows. Two hundred years, or nearly so, ago, cottagers, and even tolerably well-to-do people, were obliged to be content with wooden shutters, except in a few state rooms; but soon after, glass became much more common. The old window-tax, however, which was not removed till 1845, hindered the manufacture of glass for admitting light to our houses, as the fewer the windows, the less there was to pay for this tax. It is not more than thirty years since the second-class carriages on the South-Western had shutters of wood to pull up instead of the glass

windows now universal, even in the third class. There can be no question that, so long as an obnoxious tax existed, the health of the people suffered considerably, because plenty of sunlight is as essential to the human body as plenty of fresh air and pure water. Moreover, this tax prevented the manufacture of glass from being carried on with that energy and spirit which are so essential to progress. The result of its removal was quickly felt all over the kingdom. Windows multiplied in the houses of the great and the cottages of the poor. Hothouses and glass structures of all kinds arose, both in private gardens and public nurseries; and probably that grand exhibition building in Hyde Park in 1851 would never have been erected had not the necessary stimulus been given to the glass trade by the repeal of this onerous duty. England has no longer anything to dread from foreign competition in this material, and, as in most other important manufactures, she is well able to maintain her position. Referring to that exhibition, the like of which will probably never be seen again, because the *novelty* of the idea is incapable of repetition, we recollect especially the crystal fountain erected by Messrs. Osler of Birmingham in the centre of the transept. It was reported in the official catalogue as 27 feet in perpendicular height, and as containing 4 tons of pure crystal glass. It had no rival then, nor has any similar structure been since made. What

has, however, been done can certainly be done again: and probably an order to the same firm, or to Messrs. Chance, for a crystal fountain double the size would now be executed with speed and facility. What can be done in the way of plate-glass windows a stroll through Regent Street and Belgravia suffices to show; and here again, were a demand made for still larger sheets, they would most certainly be produced to meet it.

In one detail of the manufacture, however, England is not yet in the front rank, although considerable advance is being made in that direction from year to year. She has not yet been able to rival those magnificent windows of stained glass which used to be the glory of our abbeys and cathedrals. Certain of the tints cannot as yet be reproduced, and although there is plenty of colour in a modern stained-glass window, there is too often a want of effective blending of tints and tender gradation, which is so exquisitely carried out in the older specimens.

In addition to stained windows, coloured glass has long been used in Venice and elsewhere in the decoration of ornamental vases, drinking utensils, and other articles of a lighter description. These Venetian manufactures were, until a comparatively recent date, wholly unrivalled; but now the mode of producing them has been discovered, or at any rate a process is known and used

which produces very similar results. The colours are in many cases arranged side by side in very narrow strips, or *lines*, as they might be more accurately described; and these sometimes run straight and sometimes form spirals running round the cup or vase, or are interlaced like fairy network. Beautiful, however, as coloured glass is, it has always appeared to the writer that a thin beautifully-formed vase or goblet, perfectly colourless and transparent, without speck or bubble or striæ, has an inherent beauty and delicacy which no colouring can improve; and it may be added, that to obtain glass in this state of perfection, as needed for optical instruments, demands as much care and skill and unremitting attention to detail as the production of variously-coloured specimens. In point of fact, even now, in 1876, the lenses of Voigtlander, and one or two other foreign makers, are considered superior to any of our home productions. Possibly, however, prejudice comes into action in this matter; for though we used at one time to import all glass required for first-class optical instruments, and the names of one or two foreign makers stood prominently forward, we have of late years so improved in this respect that we now export a considerable quantity of glass for this very purpose. Probably a trial of manufacturing skill in preparing glass lenses would now end in perfect equality, as both our own manufac-

turers and foreigners are able to produce glass of equal perfection.

We must, however, now pass to the actual manufacture. All glass is not alike, and very generally different manufacturers turn their attention to the production of different qualities; for it seldom happens that any single establishment makes all kinds indifferently. The finest, perhaps, of all is flint glass, which invariably finds a place on the tables of the rich, because of its high lustre and freedom from imperfections. Then comes crown glass, German and English, which is cut up in enormous quantities for glazing windows, and for horticultural buildings. As a substitute for this, where expense is no object, plate glass now fills a very important place. Sitting by a window of crown glass, every movement of the head gives apparent motion to the landscape, because the glass, though transparent, is full of waves and inequalities; whereas plate glass, from the different manner in which it is made, is free from these imperfections, and the forms of objects are as clearly defined as if there were no such medium interposed. Last comes green-bottle glass as the commonest of all, being varied in tint and unequal in transparency, but serving extremely well for the particular purpose to which it is applied. In colour it varies from a pale green to deep purple, ordinarily termed black.

Two ingredients are always present in glass, as stated in our introductory remarks, viz., kali, which is commonly called potash or soda, and sand. The latter is the generic or general name for a variety of substances containing silex or flint. We have, for instance, the beautiful white or silver sand of Reigate—precious to gardeners; the deep-yellow and red sands, used for various household purposes; the salt sand by the sea, of which too often masons make use in the formation of mortar when engaged in building marine residences or villas, and which are constantly damp, owing to the affinity of salt for water. Alum Bay, in the Isle of Wight, as some of our readers know, produces sands of many colours, which are sold to visitors in glass bottles—the delight of youngsters, to whom the bright tints of varied forms representing hill and dale and impossible landscape scenery were, and are still, a puzzle and a mystery. When, mischievously inclined, they *chance* (?) to break these treasures, they see the mystery solved; but we will not solve it here, and perhaps spoil the pleasure of some of our young friends. Now, all these sands are varieties of a substance known to geologists as silex. Any one of them will make glass, but the greater part are in their natural state intimately associated with earthy matters, which if admitted render the glass opaque. These can be separated in a great degree by washing. Let our readers try

the experiment in this way: Take common house sand, and throw a handful into a basin of water; stir it up well, and after allowing it to settle a little, pour off the water, which will be quite thick and muddy; add fresh water and repeat the process, and presently pour this also away. After a few additions of fresh water, it will be found that the muddiness is far less than at first; and by repeating the process a few times more, the water will remain quite clear, and the sand will be quite clean at the bottom of the vessel. Pure silex, therefore, does not render water turbid, and the muddiness in the early stages of this washing process was wholly due to earthy impurities. The sand of the seashore gets washed so continually by the waters of the ocean, that it is well fitted for glass-making. This is also silex, and is chiefly made up of minute particles of quartz, pulverised by the action of sea and air in the course of many centuries. Alum Bay sand is very pure quartz, and can be obtained in any quantity, and is consequently much used; but other parts of our coasts add their share of this raw material. Land carriage of so heavy a material, indeed, regulates the quantity supplied from any particular locality, as this is of course a very serious item of expense; and glass-houses near the sea-coast, or situated, like London, upon navigable rivers, have a natural advantage in this respect over rival towns less fortunately

situated. The kali or alkali required is now obtained in any quantity from our various chemical works devoted to this special manufacture, but was formerly obtained by burning wood, barilla, kelp, sea-weed, and other vegetables, which naturally contain a considerable quantity of the required substance. The production, however, of this material is not within the scope of the present chapter to describe. Kali and silex, though the fundamental ingredients in all glass, are never used alone, as the product is not sufficiently clear and transparent, but oxides of lead and manganese and iron, especially the former, are always added, as will be presently explained.

As the heat required to fuse together the several ingredients of glass is very great, furnaces are used of solid construction and scientific arrangement, so as to produce the highest degree of heat with the least quantity of fuel. These furnaces are generally round, with a central chimney, and consist of what I may call a series of ovens, in each of which stands a melting-pot exposed to the fierce heat of the flames which curl around it. The substance put into the pots is called "frit." It is simply glass in its impure state. The sand and kali are first melted together in a furnace, or, as it would be called in the process of smelting iron-ore, "roasted," and the resulting product is broken up and piled in heaps, and is supposed to improve by age. If the sand is very fine, or

if ground flints are used, which is now seldom the case, there is no necessity for this previous roasting, and the ingredients are placed at once in the melting-pots. But when this is not the case, the latter are filled from the store of frit, and after this has been a long time under the action of the intense heat, the impurities rise to the top and are skimmed off, leaving the glass beautifully clear. The ingredients of flint glass vary with different manufacturers, but all use some flux with the sand and soda to assist the fusion and improve the quality.

White sand, redlead, pearl ash, nitre, and oxide of manganese or oxide of arsenic, is a very usual composition, and these are all intimately mixed before being placed in the pots.

Glass in which there is much lead will melt at a comparatively low temperature; and if any of our young readers have studied or played at chemistry, and bent tubes of glass by means of a spirit-lamp, they may possibly have noticed the lead reduced to the metallic state, and shining with a black lustre about the bend. Hard glass used in chemical analysis, not having lead in its composition, fuses with difficulty, and is employed where the substance to be tested has to be exposed to the heat of the blowpipe.

Oxide of lead does not give any colour to the glass, unless used in too large proportion; but oxide of cobalt, iron, manganese, and other metals, will stain the glass of

any required tint, and these are used in the manufacture of coloured glass for the windows of churches and mansions.

As we always like to add as much as we can to the interest of our descriptions of the various great manufactures, we would suggest to our readers the expediency of experimenting in a small way in glass-making with a lamp, blowpipe, and a few very simple and inexpensive materials. The use of the blowpipe is easily acquired, the only difficulty being, at first, the keeping up a constant and uniform blast of air. The cheeks are to be the spring bellows, and not the muscles of the lungs, which are to continue their usual quiet and regular action, as if no blowpipe operations were in progress. The cheeks are to be distended like those of Æolus, and the blowpipe being placed between the lips, the stream of air is to be sent through it by *the muscles of the cheeks alone*, and as the supply of air becomes exhausted, the mouth is to be refilled from the lungs by a momentary action difficult to describe. The blowpipe is so useful for chemical operations, or for soldering where neatness is required, that our young readers should certainly take the necessary pains to acquire the knack. If the cheeks are distended, the blowpipe not being used, it will be found an easy matter to breathe as usual through the nose without allowing the cavity of the mouth to have any share in the operation. It is plain, therefore, that we can isolate the mouth alto-

gether from the lungs as well as the nose, which we do by shutting the valves of communication unconsciously. Now all we need is to keep up this isolation, except when we desire to refill the mouth with air, when we momentarily open and as quickly close this valve. While, then, the cheeks are distended, go on breathing as usual, expiring and inspiring through the nose. Now let a little air pass out between the lips, still keeping up the regular breathing: you will find that for this you are calling into action the muscles of the cheeks. As the mouth gets emptied, try and refill it by a momentary action of the tongue, which is the valve, against the roof of the mouth. It will make a little noise something like the word "tup," and the mouth will be full of wind instantly. This is the whole secret of blowpipe work, and a quarter of an hour's determined practice will suffice to get any one accustomed to the management of the breath. The lungs must on no account be used to act directly upon the blowpipe, but only to fill the distended cheeks.

Now place upon a bit of pumice-stone—which any painter will give you—a little sand and soda (or potash), with a small portion of redlead or minium in powder, and send upon this mixture a stream of flame from a spirit-lamp by means of the blowpipe until the ingredients fuse together into a bead of glass. Of course you will need a very little of each ingredient, as the whole bead will be about the size of a peppercorn or less, according to your

power of using the blowpipe and the size of the flame. A little turpentine with the spirit of wine (not enough to make the lamp smoke) will materially increase the heat and help the operation.

A softer glass may be first experimented on, made by fusing borax, which, after boiling up in an eccentric fashion, will settle down into a clear bead; and if this is touched with a drop of nitrate of cobalt, or if a little morsel of the powdered mineral itself be added, a beautiful blue bead will be the result. In the same way a little rust of iron, or a little of the salt called sulphate of iron or green vitriol, or manganese, copper, and other substances which contain metallic oxides, may be tried, and the colours noted. In these simple experiments the whole process of glass-making may be learned in a practical manner, and the details will be thoroughly understood.

The process of glass-blowing may similarly form a fireside amusement, experiments being made upon the glass tubing which may be obtained at the chemist's. But we must return now to the manufacture as conducted on a large scale in glass-works.

The pot of glass having become thoroughly melted and clear, and the scum removed, which is called sandiver or glass-gall, the workman dips into it a tube of iron previously made hot, and gathers upon the end as much

glass as will cling to it, and when this is slightly cooled, he repeats the operation until he has as much upon the tube as he requires. He then reheats this lump of glass at the furnace mouth, and when it is soft enough, allows it to run partly off the end by holding the tube in a perpendicular position a few seconds. Then by blowing down the same the glass swells out like a bladder or soap-bubble into a globular form. Probably this will not prove large enough at first; but by holding the glass at the mouth of the furnace it becomes soft enough to be still further acted on by the breath, and gradually—but quickly—swells to the required size. If this requires to be flattened (as, for instance, for a glass jar such as pastry-cooks use), it is rolled while hot on a flat slab of iron mounted on legs like a low table until it takes the necessary form. If, on the other hand, the globe is required to be elongated to a pear-shape, the blowpipe, which is about 5 feet long, is swung round the head, and the centrifugal force acting on the softened glass causes it to extend lengthwise. There is nothing more marvellous to a looker-on than to see how rapidly, by such simple means as these, differently-formed articles are produced; and certainly, to see the way in which the workmen toss it about, no one would suppose glass to be the fragile article that it is. In short, when soft, no material is so easy to work, and scarcely any requires for its manufacture tools so

simple and few in number. If, for instance, the globe requires to be spread sidewise like fig. 62, a pattern given to some decanters, and vessels liable to be upset,

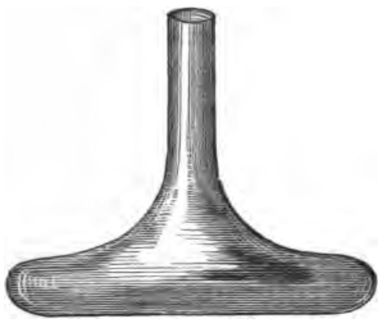

Fig. 62.

the workman rests the blowpipe horizontally upon a bar of iron, and gives a rotary or twirling motion to it, and the form required is instantly assumed.

While hot, glass is cut with perfect ease by shears or scissors; and it is detached when necessary from the blowpipe or pointel (which will be presently spoken of) by being touched with a rod of iron wetted at the end. The pointel is a solid rod, rather larger at the end than the blowpipe. This is dipped in melted glass, so that it shall take up a small portion on its extremity. This being applied to the globe of glass on the blowpipe, sticks to it, and the latter instrument is then detached by a touch of the wet rod, and at once replenished for the use of the blower, while another workman takes the pointel

in hand, and proceeds to fashion still further the partially-finished article at the end of it. We will suppose, first of all, that this is to be formed into a sheet of window-glass, which at first sight would appear a very unlikely thing to be thus made. The operation, nevertheless, is extremely simple. The man with the pointel holds the globe of glass, which is now open at the end where the blowpipe was attached, to the mouth of the furnace until the glass is soft. Resting it on a horizontal arm of iron, he twirls or trundles it rapidly, while an assistant with an iron tool opens wider the neck of the globe. Continuing this rapid rotary movement, the glass all at once seems to fly wide open, or "flashes" into a round disc, of which the punt is the centre, and the bull's-eyes, as they are called, used sometimes for the windows of stables and out-buildings, are the central parts of these sheets where the pointel was attached. In cutting up the discs for house windows, these parts about the centre are cut out, and the sheet divided into halves and quarters, such as may be seen packed in wooden crates at any glazier's shop. This was at one time the only method known of making sheet glass, but it will be readily understood, from the very means employed to produce it, that it is always wavy, though much less so near the outer edge, which formed the circumference, than near the bull's eye or punty mark.

The next step in improvement of window-glass was as follows: The globe is produced as before, by blowing; and then after being reheated is rolled upon the iron slab or maver, so as to reduce it to a cylindrical form. To assist in this the workman stands on a high stool, and swings the glass to and fro, so as to elongate it while hot by its own weight, while he still keeps up the blowing. By this means the globe is considerably lengthened, and takes a pear-shape. An assistant now with a pair of shears cuts open the lower end, and also enlarges with this tool the hole thus made until it is the size of the largest part of the glass. The blower assists the operation by a few dexterous rotations of the blowpipe until the form assumed is that of a cylinder open at one end, but attached to the blowpipe at the other, which is still more or less globular. A pointel with a cross-piece at the end, which is of such length as just to fit the inside of the open end, is dipped in melted glass and applied to the cylinder, which is itself made hot, and attaches itself to the latter firmly, allowing the blowpipe to be detached from the other end by wetting the hot glass as previously described. The end thus detached is now heated, and opened just like the first, so that there is now a cylinder of glass open at both ends attached to the pointel. An assistant now, while the glass is hot and soft, cuts this cylinder open from end to end, and lays it flat by unrolling it on an

iron slab, upon which it is laid at once in the annealing-oven. Like all operations of the glass-house, this is very simple, and to the spectator looks also very easy; but it nevertheless requires skill and strength, for glass is a heavy substance.

All glass articles, if merely left to cool, would fly to pieces with a touch—and often without, on being exposed to change of temperature. They therefore are placed in an annealing-oven. This has a fire at one end below it, so as to be very hot; but as it is of a long shape, the other end, which is also open, is tolerably cool. The articles are put in shallow iron trays, and while still very hot, are placed at the furnace end of the oven. The next tray introduced pushes the first farther on, and thus gradually all reach the cool end; and after this process they will bear all the ordinary usage and changes of temperature, so that you may pour boiling water into a well-annealed tumbler without breaking it, but a thick and badly-annealed glass will crack immediately.

Such is briefly the process of glass-making, and there is no manufacture that surprises a visitor more than this. The facility with which in a few moments the material, which we only regard as a brittle substance, flashes into various forms, the simplicity of the different operations, the skill and ease, to say nothing of rapidity, with which the

work is carried on, are indeed marvellous; and if this little volume could have been extended to include details of cutting and engraving glass, casting, pinching, and stamping it, colouring it to represent precious stones for cheap jewellery, with various other particulars all of equal interest, our account would have been much more complete. We must, however, reserve this and much more for a future occasion, as Glass-making almost needs a volume to itself. What we have given is little more than a faint sketch of the process, but sufficiently detailed to justify us in hoping that the result of our labours may be an increase of our boys' knowledge and extension of their pleasure. The acquirement of knowledge of all kinds is delightful to any veritable young mechanic, and *all* our boys, whether mechanical or not, ought to make themselves acquainted with the manufactures of their own and other countries; for it is to these industries that we owe our present greatness, and by them we may well hope to attain still higher degrees of refinement, culture, and civilisation.

CHAPTER XVIII.

SCIENTIFIC MACHINES.

THESE may be said to differ from those already described as not being manufacturing machines, although even in this respect no hard and fast line can be drawn. An electric machine or galvanic battery, for instance, though primarily it would come under the head of scientific apparatus, becomes a manufacturing machine when used for electrotyping and electroplating, as the telegraphic apparatus becomes a printing-machine when fitted with additional mechanism, registering automatically the passage or stoppage of the electric current. As the telegraph is now to be found in almost all towns, and will probably not be long absent even from country villages, we will treat of this first. We cannot tell our readers what electricity is, but we may compare it to light and heat, in making us conscious of its presence by its effect. It may also, like these, be

regarded as flowing onward in waves or currents from the source which produces it; and we can, as might be expected, deflect it from its course and turn it into another direction, or altogether check its progress. Heat and electricity we can also accumulate and store up; but light, though it is very probably another form of these, we cannot as yet by any known means entrap. Our most reliable scientific men, or "Scientists," have long regarded these three elements as one and the same, under different conditions, but they are so subtle in their nature that many difficulties exist in proving their identity. This is, however, certain, viz., that electricity will produce light and heat; and heat and light will apparently return the compliment—heat most decidedly will, and light gives tokens of so doing, besides being possessed of many qualities common to the other two. The universe is perhaps the great storehouse of electricity, but there is no reason to believe the high-flown statement of advertisers of galvanic appliances, who state in big letters in every paper that "Electricity is Life." It is quite true that within a certain period after death an electric current will cause a movement of the limbs, or even renew the action of the heart; but when death has once actually taken place, and the soul has quitted its mortal tenement, no amount of this subtle fluid will give back the life that has become extinct—the fire once out may not be rekindled until the

word which first lighted shall renew it. But electricity, nevertheless, acts wonderfully and powerfully upon the human frame. Exciting the nerves, it gives motion to the limb by causing violent spasmodic action of the muscles, and if of sufficient power will even paralyse or kill the experimentalist.

Very gently and continuously applied, it is in many diseases of the nerves, especially in rheumatism, of great service as a curative agent, by stimulating into action nerves which have ceased to do their work properly. It is not, however, by any means an agent to be trifled with or indiscreetly used, and any one of delicate constitution might be seriously injured by injudicious experiments with the electric fluid. We have said that electricity is apparently laid up in the great storehouse of our universe, and so it is, but not in a state of tension; and we may explain this by comparing it in its quiescent state to an uncoiled powerful spring, or to uncompressed steam or air in which enormous power exists but is not sensibly apparent. Wind up the spring, or compel a given bulk of air or steam to occupy considerably less space, and we have a very good representative of electricity in a high state of tension, ready to burst forth in the lightning flash, capable of rending trees and rocks, and depriving instantly of life any animal or human being that may intercept its course. Yet that fiery dart, so awful in the

intensity of its brightness, so fatal to its victim, can be controlled and directed in its course, entrapped, subdued, and made the willing servant of mankind. You might stand within an iron room, for instance, in the wildest storm that has ever burst from heaven, and though a hundred flashes fell upon that metal barrier, you would be perfectly safe, although the thickness of the shield were no more than that of cardboard. We cannot, however, here enter very deeply into the theoretical part of our subject, and it must suffice, for the present, that we can conduct, or deflect, or check the flow of the electric current at pleasure. We need not go to the clouds for our supply of the subtle fluid, for although, perhaps, it would be incorrect to say that we can *create* it, there is not a doubt about our capability of producing it, or at any rate of giving it such a degree of *tension* as will render it an active agent in our hands. We can do this in two ways—first, by friction of certain easily obtainable substances, notably glass, and resin, gutta-percha, and vulcanite; but as these three are so far identical that they are exuded as gums from trees, except that the latter is also compounded with sulphur (itself an exudation from the earth), we may still divide the substances from which electricity may be produced by friction into *vitreous* or glassy, and *resinous*, as it is a convenient division to make.

By rubbing dry glass or dry resin we can, under certain conditions of insulation, make the electrical state of such substances visible by a spark which they respectively give off, accompanied by a snap; and after this spark has been emitted, the tension of our electrical spring ceases, and whatever electricity still remains is quiescent and inactive. But frictional electricity is not practically well adapted for telegraphic purposes, for which we require rather a continuous stream of tolerably high tension, and not a sudden discharge like the flash of lightning, or the instantaneous release of a tightly-coiled spring. We require, if I may so term it, *pressure*, and not a *blow*. The electricity is usually called galvanic, from the name of its earliest discoverer, and seems to depend upon chemical, rather than mechanical, facts. If we place a piece of copper and a piece of zinc in a solution capable of exerting a powerful action on the one and not on the other, an electric current is at once set up; and if the two are connected at the top by a wire, which is a good conductor of the fluid, the latter will flow from the zinc along the wire to the copper, and thence to the zinc again. With these simple elements, salt-and-water will be sufficiently active as an exciting solution, and is for our young friends much better than sulphuric acid and water, which, though it produces a more powerful action on the zinc, is also ready to do the same on the clothes

of the operator, the result being a decided shock to those who have to pay the piper. Salt-and-water, too, being less active, will continue to excite the "battery," as it is called, for a much longer period, and powerfully enough for the purpose of experiment. But how can we tell that any electricity is passing? Probably our readers know well, and some, no doubt, possess pocket-compasses, some of which are made to hang as charms from the watch-chain. Let them stand their little battery on the table, in such a position that the wire (which should be of copper, and soldered to the zinc and copper plates, so that one is at each end) shall stand north and south. Then let them bring under its centre the compass, whose needle, of course, also points in the same direction, and let them note the result. The needle will point east and west, standing at right angles to the wire. This is always the effect produced by a current of electricity passing round a magnetic needle, and if the battery is very powerful, the wire between its ends might be of nearly any length, but the same effect would be produced on any number of compass-needles placed in its course. This is the electric telegraph in its most simple form, but we need a power of controlling the motion of the needle before it can be made to serve our purpose. Now, while the needles are standing at right angles to the wire, or as nearly so as the strength of the current will make

them, let us snip the wire in half with a pair of nippers. Don't take your sister's scissors unless you've no better tool at hand! Instantly the current ceases, and the needles stand north and south as before. Bring the ends of the cut wire together again, and see! the needles go back again. Here you observe we have the elements, at all events, of a very beautiful machine; we need only agree to make any letter we wish to express by moving the needle once, twice, thrice, or more times, and we can spell out words—slowly, it is true, but certainly. Now, if we give the wire a turn round a compass at one end of a room, and carry it on, and give it a turn round a second at the other end of the room, and arrange that the cut ends of the wire shall be within easy reach of one of us, then the other may go and watch the other needle, and as both will make similar movements, they will represent telegraphs at London and York; only, you see, in the case supposed, one must do all the talking, and the other all the reading, for he can't answer back, which would, I daresay, be very aggravating to most boys. Moreover, our alphabet would be terribly puzzling, and take no end of counting. We can remedy this, however, for there is a way of making a magnetised needle move to right or left at pleasure, which will give us two motions instead of one, and make a shorter number of oscillations answer. We must also, for practical purposes, contrive to get greater

power, and it is more convenient to let the needle hang upright before us than to have it in a horizontal position, so that we have to look down upon it. Whichever way it hangs, however, the principle is the same, and if we cause a current of electricity to traverse a wire which is coiled round it, such needle will be acted upon by it. It is important to note, however, two particulars relative to the effect produced upon a magnetised needle by an electric current.

If this current passes from north to south above the needle, the north pole of the latter will turn to the east. If the same current is caused to pass *below* it, but in the same direction, *i.e.*, from north to south, the needle will be deflected in the opposite direction. Now, if instead of this current being carried once across the path of the needle by a single wire, we coil the wire many times round it, so as to multiply the power, it is plain that the effect produced will be many times greater, and as, in addition, the current will thus pass above and below at the same time, but in contrary directions, the needle will be doubly influenced. But at the same time that the electric current tends to move the needle out of its normal position, the magnetism of the earth tends to draw it back again to stand north and south as usual; hence we have a certain resistance to contend against, and we should gain power by getting rid of it if possible. We manage

to do so in electric telegraphs by very simple means, viz., by what is called an astatic needle. This is simply a pair of needles on one common axle, or suspended to the same support, the north pole of one being over the south pole of the other. As the earth's magnetic action thus ceases to act upon the needles, it might be supposed that the influence of the electric current would also be lost, as the tendency of the one or other pole to turn east or west, instead of north or south, would seem to be done away; but such is not found to be the case. Although the poles of the needle are neutralised, it will still tend under the action of the electric current to stand at right angles to its former position, and whether it will move one end (we can call it the north or the marked end) to right or left, *will depend upon which direction the current travels in round the coils of wire;* for we can send it either way at pleasure, as will be evident on consideration. Let us, for the present, suppose our simple battery to be in use as before, with the wire cut so that we have one end attached to the zinc and the other to the copper. We will also suppose that we have our needles, and the coils surrounding them, attached to some sort of stand, with the ends of the wires projecting. Now, the current of electricity flows out from the battery at the copper end, and passing through the wire enters the battery at the zinc end. It is plain, therefore, that we can apply either end of the coil

to either end of the battery at pleasure, and that thus we can make the current enter the coil and traverse it from right to left, or from left to right, and this will cause the marked end of the needle to move right or left accordingly. Of course, when we come to the practical working and construction of the telegraph, some means must be devised for instantaneously altering in this way the direction of the current, for it would take too long to be obliged to do this by constantly shifting, by hand, the four ends of the wires; this is effected by what is called a commutator (from *muto*, to change), and the simplest form, perhaps, for merely experimental purposes is as follows: It is to be remembered that we want metallic communication—the current will not pass through wood, bone, ivory, sealing-wax, gutta-percha, &c. &c. The plan here given is from a small elementary work by Angell, but there being no diagram of it in that book, I have been obliged with some little difficulty to make a drawing from the description there given. A (fig. 63) is a mahogany board, which is, together with the battery, drawn as it would appear to any one looking down upon it from above. The needle and coil would also thus be horizontal, although in practice it stands vertical. F F are two slips of hard brass, half an inch wide and 3 inches long; G, a T-shaped piece of the same width. These do not lie flat, but are bent so as to spring up about half an inch from

the board, and the long strips remain in contact with the cross head of the T-piece, unless purposely pressed down. E is the battery, here represented of an old pattern, consisting of a number of cells full of sulphuric acid and

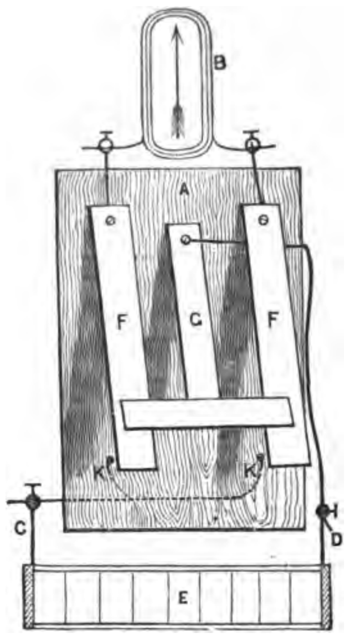

Fig. 63.

water, acting upon a series of alternate zinc and copper plates ; and the last in the series at one end is zinc, and its fellow at the other is copper. The current, multiplied greatly in power by proceeding from many plates, instead of a single pair, leaves as before at the copper, which forms

one end, and returns to the other after traversing the wire and coil. At K K are two studs, being the ends of a long bent staple of stout wire put in from below, the ends standing up a little distance, so that either piece F F, if pressed down, would rest upon a stud. A wire soldered to this staple goes to the binding screw C at one end of the battery, while a second wire in contact with G goes to the other end. This should rather be represented, like the staple, as being *under* the board, and would be soldered to the screw by which the piece G is fastened to the board. Similar wires, attached to the screws which hold the long strips G F, are, by means of binding screws, placed in metallic connection with the ends of the coil. By this instrument the current flowing from C, the copper end of the battery, can be made to traverse the coil in either direction, according as E or F are pressed down upon the studs below them.

Let us press down the right-hand spring F, and trace the course of the electric current. Beginning at C, it will pass along to the right-hand stud on which the spring is now resting, thence along this spring to the binding screw, and round the coils. Then, leaving the latter at the other end, it will pass to the other spring F, thence to G (because not being pressed down, it is in contact with G, but not with its own stud), thence by the screw in G and wire attached to D, the zinc end of the battery.

To make the needle move in the other direction we must reverse the course of the current thus: Taking off the finger, the right-hand spring F will rise, and touch the T-piece as before. We now press the other spring down upon its stud. The current will then pass from the battery to this stud—along its spring—round the coil *in the other direction*, down the right spring to the T-piece, and, by its screw and wire, to the zinc as before. In its course it will have deflected the needle. Thus we can instantaneously cause the latter to oscillate as we please, for the action is perfectly instantaneous, as the current would go round our globe in one-tenth of a second. We now can very much simplify our alphabet. We have the movement of the needle's point to the right to signify one letter, to the left for another, twice to the right and once to the left for a third, twice to the left and once to the right for a fourth, and so on. In practice, however, the single needle is now generally replaced by two hanging side by side, each with a coil of its own, thus increasing very considerably our power of conversation by signs, because with two needles half the oscillations only will be necessary. Even with these it may be easily seen that a good deal of practice is needed to enable messages to be sent and read with speed and facility. Such is the principle of a needle telegraph, the detail only being modified, as we shall proceed to relate.

We must now say a word or two more about the battery, and then proceed with a description of the manner in which the line-wires are practically arranged. We have shown that a plate of copper and another of zinc, placed together in a solution acting more upon the one than upon the other, generates a current of electricity. During this process the zinc, which is called the *positive* element, is gradually dissolved, and gives off from its surface a quantity of hydrogen gas, which you will see, if, as I hope, you make experiments upon the subject, rising in copious bubbles through the liquid, which, if of sulphuric or muriatic acid and water, appears boiling, so rapidly is the gas disengaged. A good deal of this is waste of power and of material, and the zinc is usually amalgamated with mercury, by being rubbed with that substance while wet with acid and water. The surface will be entirely coated, if the operation is carefully carried out, and will be perfectly bright, and, in this state, will not be attacked so fiercely, but will give out a sufficient quantity of electricity, and the action will continue for a much longer period. But in a battery of this kind it has been found that another drawback exists. Bubbles of hydrogen cover the copper plate and do not readily leave its surface; a deposit of zinc also takes place upon it, whereby its action is first impaired, and ultimately ceases entirely. If this is the case in a single cell, it is

evident that it will be so in any number; and this defect for some time gave great trouble, although it was usual to make telegraph batteries in the form of a long box with divisions, in each of which was a zinc and a copper element. Sulphuric acid and water was used as the exciting fluid, and very often this was poured upon sand, with which the cells were filled, by which there was less danger that the solution would get upset or wasted, while at the same time it was considered that this material exercised a certain degree of influence in keeping clean the surfaces of the two metals.

Our present papers not being devoted to the theory of Voltaic electricity, we cannot enter at any great length into the laws of electric currents; but upon one point bearing specially upon the batteries used for telegraphic purposes we must of necessity say a few words. If the zinc and copper plates are respectively of large size, they will give off electricity in great quantity. It will not, however, provide exactly the power required. It is, to use our old type, a strong spring uncoiled. We coil it by multiplying the number of cells, connecting the zinc of one with the copper of the next; and in telegraphy, while the oblong wooden troughs of many cells were used, it was usual, for long distances, to connect these together in a similar way—the last cell of one with the first cell of the next, and so on. If *quantity*, however, is required,

two such batteries can be used in a different way, by connecting all the coppers and all the zincs together as one, so as practically to compose two large plates of the metals. These will act in this case like a single pair. But Pro fessor Daniell, whose name is an honoured one among electricians, set to work to find a substitute for the zinc-and-copper arrangement, owing to the defects of these already stated. He therefore had to consider two points. First, the deposition of zinc upon the copper; and secondly, the drawback caused by the bubbles of hydrogen resting upon the plate. Of the amalgamation of the zinc we have already spoken, and the next step was to enclose this metal in a porous case with its own exciting fluid, either sulphuric acid and water, or sulphate of zinc in the form of a concentrated solution; and to place the copper in an outer cell, which was filled with a solution of sulphate of copper. This being decomposed by the electric current, constantly deposited a fresh coating of the metal upon the copper plate, thereby renewing its surface and using up the hydrogen that would otherwise have rendered the battery defective.

To keep up a supply of copper deposit, crystals of the sulphate of copper salt are laid upon a perforated shelf, so as to touch the solution and gradually dissolve, being replenished when necessary. The porous diaphragm was originally of sailcloth, but brown paper or bladder was

also used. These have now given way to plaster-of-Paris, which is formed into the shape required, and answers the desired purpose admirably. Of course it matters little whether the cell is round, to receive a cast rod, or flat, to contain a plate of zinc, and the copper cell may surround it, as is often the arrangement, or the contrary plan may be used. For electric telegraphs the form preferred is that of a trough about 2 feet long, divided into compartments by water-tight divisions, and subdivided by plaster-of-Paris partitions. The plates of zinc and copper are joined in pairs by a copper band at the top, which being bent over in the form of an arch, brings the copper and zinc plates face to face in the cells, but with a porous diaphragm between them. The solutions are, as before, sulphuric acid and sulphate of copper. From what has already been stated, it will be understood that at each telegraph station there is needed a battery, and also a coil or coils with their respective dial-plates. After the current has passed through the instrument at the operator's station it does not return at once to the other pole of his battery, but goes on to the coil at the distant station, and thus deflects the needle at that place in the same way as it deflects it at the sending station, so that it is read letter by letter by the one who is despatching the message, and also instantaneously by him who is intended to receive it. It may also evidently deflect needles similarly fitted with coils at any

number of intermediate stations. Having passed the last coil in the series, the current used to be brought back by a return wire to the other pole of the sender's battery.

What a splendid discovery it was! and how rapidly it has become a practical medium of business, and also of private correspondence! Borne now by a wire cable across the Atlantic Ocean, the electric fluid, once toyed with only in the lecture-room, now bears message after message with lightning speed from one continent to the other. Whatever is taking place in one country is instantly reported in all directions, and the news upon which perhaps depends a nation's destiny is read by the excited throngs thousands of miles away. Before the sound of the last cannon-shot has died away, the victory or the defeat is known in every land; and indeed, as some of our young readers will understand, a telegraphic report is announced in one country before the event has actually occurred, owing to the difference of time between eastern and western lands. When the telegraph was first invented by Wheatstone upon the foregoing principle, several wires appeared to be necessary to convey messages to different parts, and in all cases a return wire was used to carry back the current to the battery of the sender. But it turned out on further experiment that this was unnecessary, as the earth itself was ready to be man's slave, and to transmit the current unaided; hence one wire was immediately done away

with. The negative pole of the sender's battery to which the current has to return is simply placed in metallic connection with the earth by a wire with a plate of copper attached to it, or very often it is simply led into a pit with coke in it, or attached to the gas or water pipes. It seems not to be of great importance how this is carried out, so long as the wire is capable of readily conducting the current to a bed of damp earth. The negative wires of all the batteries are similarly treated, and according to the theory commonly accepted, the electric current finds its way back through the earth as readily as by means of a metal conductor; but don't forget, boys, to experiment on this, for there are yet secrets to be evolved, or we are mistaken.

But for our present purpose we may consider the connection between the poles of the battery to be completed by what is called the earth circuit, the effect being the same as if the current passed from one terminal to the other through a connecting wire. The transmitting instruments in use are not like that illustrated, as the motion requires rapidity, which could not be attained in this form of apparatus. The coil is placed, as stated, upright, so that it appears something like the hand of a clock. The outer or reading needle, however, is not of metal but of ivory, and is simply fixed to the end of an axis, which carries the astatic needles within the coil.

The working parts are concealed inside the case of the instrument, and on the outside is merely the ivory needle, prevented from oscillating too far to the right and left by little ivory studs; and the handle is below, by which the commutator is worked. An alphabet or a code of signals is engraved upon the dial-face to assist the memory. The handle alluded to is attached to the end of a horizontal wooden roller, capped at each end with brass, and there are slips of brass let into it lengthwise, which reach to these caps. Two brass springs rise on each side resting against the roller, so that by turning the latter a little distance to right or left, these springs can be made to rest on the brass slips, completing metallic connection with the battery, or upon the intermediate wooden part which breaks the connection. By moving the handle to the right, one slip comes into action, and a movement to the left does the same with the other, the needles moving right or left accordingly. After what has been said, the instrument will be, probably, understood without a special drawing.

There is yet another system of electro-telegraphy dependent upon quite a different principle. In this the message is not conveyed by the oscillations of a needle under the influence of an electric current, but by the action of an electro-magnet upon certain clock-like mechanism. This principle we must endeavour to explain,

as it is applicable to other than telegraphic purposes, and if it were not for the drawback of costliness in use, would very likely supersede steam, or at any rate hold an important place beside it as a motive agent. It was known very early to experimenters upon Voltaic electricity, that if a sewing-needle were laid within the coils of a wire attached to a battery, it would become magnetised, as also if a charge from a Leyden jar wire passed through it. But it was subsequently discovered that if a bar of soft iron were made the centre or core of such a coil, it would retain its magnetism only so long as a current from the battery continued, but that the moment connection with the latter ceased, the iron would return to its normal unmagnetised condition.

Suppose, therefore, a bar of iron fixed vertically upon a stand, and surrounded by a closely-wound coil of *insulated* wire. If a keeper, *i.e.*, another bit of iron, were suspended a short distance over its upper end by a light spring, this would be attracted every time that connection was made with the battery, and when the connection ceased, the spring would raise it to its former position. A short bar, 2 or 3 inches long, suffices for experiment, and any little bit of iron may be fixed to the end of a piece of watch-spring, so as to keep it one-sixteenth of an inch from the end of the bar. The wire, we have said, must be *insulated, i.e.*, covered with a layer of non-

conducting material, generally silk or cotton wound round it by machinery, but sometimes gutta-percha. The reason is evident, for if the coils of wire touched the iron and also each other, they would simply act as one plate, becoming a mere solid conductor. But if the coils are insulated, we can carry a current round about the iron as many times as we please, thus multiplying greatly the effect of the electric current. Suppose now—to make the matter as simple as possible—that every time the keeper descends upon the magnet, it represents a letter or sign, as with the oscillations of the needle. It is plain we can devise a code of signals as before, or by simple mechanism we can make each movement of the keeper act upon a needle or clock-hand, as in the telegraph described. Thus we can use this electro-magnetic power as easily as the other. This, however, is not the actual way in which the telegraphic apparatus has been arranged, but we shall revert to this presently. The first use made of electro-magnets in respect to the telegraph was the sounding of a bell as a signal to the distant station to be ready to receive a message. As soon as the bell was heard, the man at the receiving instrument replied by moving the needle once to the left, to show the sender that he was prepared to attend. These bells are not so general as they used to be, however, for they made a deal of noise in an office, where perhaps there were a

dozen or more instruments; and, generally speaking, a signal is announced as coming, by the sender moving both handles to and fro with great rapidity, which, causing the needles at the distant instrument to click incessantly against the ivory studs on each side of them, suffices to attract attention. The electric bell, however, has recently been introduced into both hotels and private houses, doing away with cranks and fittings, which so continually get out of order that the change is found to be a considerable benefit. A comparatively small constant or Daniell battery in the cellar will continue months in action without attention, and is easily replenished when desired. In the telegraph instruments the bells were usually on the top of a small case containing clockwork, above the instrument. This was wound up, and the electro-magnet did no more than release a catch for a few moments, allowing the striking apparatus to run down as in an ordinary timepiece. When, however, instead of many strokes of the hammer, only one is required to be made, no clockwork is necessary, as the sudden attraction of the keeper can be used directly, being made to act upon the hammer itself. The distance, however, through which attraction is exercised between the magnet and keeper is very small, and the power of attraction diminishes as the square of the distance; *i.e.*, if an attractive force of one pound is exercised upon a keeper

when it is one-twentieth of an inch from the end of the magnet, it is but a quarter of a pound at the distance of one-tenth of an inch. This is the drawback to the use of such a power in practical machinery. It is a *great* power, but it acts only so close to its source as to be unavailable, and it is also far more costly than steam, owing to the rapid consumption of the metal under the action of the exciting liquid. Whether some other source of electricity may be one day discovered, rendering its application less costly, we cannot say; but there is here again something to occupy the attention of our boys, and they can indeed experiment largely upon Voltaic electricity long before their jackets and knickerbockers have developed into "tails" and those unpicturesque articles which disfigure our legs.

CHAPTER XIX.

THE GREATEST MACHINE OF ALL.

AND now, boys, we must say a few words about the great human machine, whose value transcends all which have been described in these pages. And of this there are moving parts very similar in arrangement to some of those which we have set before you. But when we come to the more intricate details, and especially to the secret of the motive power which drives the machine, we find a limit to our knowledge, and confess at once that we know very little about it. For there comes a time when this great and mysteriously-made machine ceases to do its work; frequently there appears, on examination, nothing particular the matter. Every joint, and bone, and muscle is in its proper place, and if we could but rekindle the fire which has suddenly gone out, all would work as before. But that fire of life is extinguished,

and human hand avails not to relight it. And for want of it the machine has become useless for worldly work, and we lay it in the grave to become gradually dissolved into its component particles, and then a few centuries may pass by, and no visible trace can be found. Our machine has become dust—as truly dust as the coffin of wood in which we laid it—as truly dust as the iron, and the brass, and the wood of which any other machine is made, will become, after a similar interval; so that to the turner and his lathe, to the weaver and his loom, to the carpenter and his tools, there is but one end, and that end is dust. Theoretically, the motive power of the machine is centred in the brain, and thence is carried (just as we might convey the electric current by a metallic conductor) down the spinal marrow, which is a continuance of the brain substance, to the nerves, which radiate from it like white threads to every part of the human frame. These nerves, however, have their own centres of energy, reminding us again of supplementary batteries, sometimes added in a circuit to supply additional power. These are called, technically, nervous "ganglia," and are arranged where it is required to concentrate nervous force. There is such at the pit of the stomach, called the solar plexus, and a sudden blow upon this has caused instant death, and is always dangerous. If the nerve connection is severed, as, for instance, by any

injury to the spinal marrow, the parts below it are so far dead that they cease to be under the control of the will, and then we call them paralysed. As long, however, as the connection with the brain is perfect, and the nerves, or human telegraph wires, are in sound and serviceable condition, a message is instantly conveyed from the brain to any part of the body, and motion is the result, so that the will and the resultant action are almost simultaneous. This is, however, comprehensible only as electricity is comprehensible. We find, experimentally, a power existent, and that under certain laws it can be made subservient to our desires; but what the power is, how the human mind acts upon the will, and the will upon the nervous system, this is the mystery we cannot fathom—the mystery of life. And treating of life, we allude here to physical or animal life generally, because the animal world displays the same mysterious connection between the will and the brain, the spinal marrow and nerves and muscles, as is found in ourselves. The horse wills to go forward, and it does so, or it wills to jib and kick off its rider, and there is no doubt about that will inducing the energetic action of the necessary muscles. Many of our boys have had "croppers" in this way.

Passing from the motive power to the mechanical structure of the body, we shall find, first of all, a strong but light framework, which we call the skeleton, to

which are attached, by wonderfully-arranged joints, the various limbs or movable levers whereby the work of the machine is carried on. The main difference between this frame and that which we arrange ourselves is that it is nowhere absolutely rigid, being, as it were, built up in sections, each of which is attached to its neighbour by cartilage, which may be compared to very stiff india-rubber. Even single bones, which at first sight may appear to be composed of but one piece, will be found, on examination, to have the enlarged ends, which form the actual hinges of the joints, attached to the shank by this substance, which, being partially dissolved by long boiling, is frequently seen to have become separated, especially in such young animals as lambs and calves. In old carcasses much of this substance ossifies or becomes absolute bone, losing, of course, its pliability. It is partly from this cause that you boys are able to beat your elders at various athletic exercises. There is more pliability in your cartilage, and your joints are more flexible; but then, on the other hand, your muscles are weaker, and your brain—well, we won't say anything about that, it is active enough for your requirements, and has wisdom enough for your years, and we should not like old heads on young shoulders, nor that you should begin very early in life to experience the various worries which assail your elders. We are content to be the "old

fogies" now, and some day old fogyism will get hold of you, and your levers and cords, and system of joints and pulleys will begin to fail as ours are now doing. So make the most of your boyhood, for it is the most precious time of life, if only it is used well and honourably as it ought to be.

There are altogether about 252 bones in the human skeleton, so that the wonder is not that rude shocks occasionally dislocate joints, but that we are able to do so much, and to endure so many vicissitudes, without putting the whole machine into irreparable disorder.

Suppose that we break any part of a machine of wood or metal, we either glue, or solder, or weld the parts together; and very often 'tis at best a clumsy job, and the united parts are weak. But if we break a bone of the great living machine, nature will make a splendid job of mending it, if only we can keep the broken ends together immovably for a few weeks. First of all, inflammation of the part ensues, giving pain, but originating the cure. Then there exudes from the broken ends a fluid called lymph, which thickens into cartilage, and then ossifies into bone, and the place where fracture occurred is actually stronger than before. This, at any rate, is a theory of the curative process commonly received, but it is only right to state that some doubt has been cast upon it, because it is found that pure bone,

without its natural sheath or thin covering of periosteum, as it is called, will not then unite, so that it is quite possible that the gelatine or cartilage is provided from this sheath and not from the broken ends of the bone. At all events, cartilage is first formed, and then, by a deposition of lime, becomes osseous or bony.

Here again, you see, boys, the mysterious work of life, the *vis medicatrix naturæ*, or natural tendency of nature to repair injury. I fancy we might leave a broken bit of wood or metal a precious long time in splinters without such reparative process taking place; but nature provides a regular system of welding broken bones, and the points of union are often less visible than those of the smith's welding.

But we will now pass on to the consideration of the strictly-mechanical arrangements of the human body. Let us consider the arm first of all, as it is practically hardest worked of all our members. Here fig. 64 is its skeleton. In the hand is a weight B to be lifted. Now, we find here a lever of the third order, and you will remember that in this case there is loss of power but gain of speed. It would scarcely be convenient to be obliged to move our hand slowly; we want it generally to move through a good deal of space in double quick time, and to do so with moderate force. The elbow-joint is the fulcrum upon which the forearm, from the

elbow to the hand, moves, and the latter is the rigid bar or lever. The power is obtained from the contraction of the muscles, one end of which is inserted below and the other above the joint. C might be a doll's arm of the usual Anglo-Dutch elegance of form, with a band of indiarubber to represent one of the muscles by which the

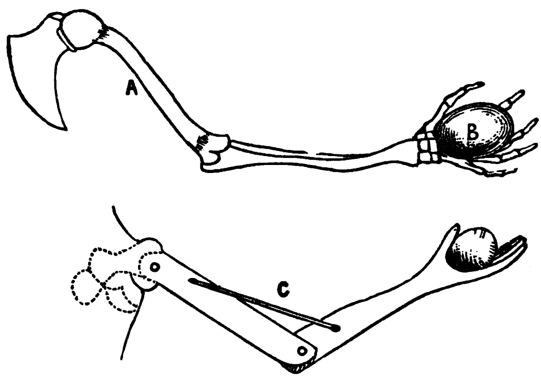

Fig. 64. (The bones of the forearm are badly drawn, but will suffice for the present purpose of explaining their leverage and action of the muscles.)

forearm and hand are raised. The hand, you see, will describe a large arc, while the point at which the indiarubber is fixed makes a small one, and this point being so near the fulcrum, shows us that not much power is obtainable, the strength of our indiarubber spring being more than its total amount, because of its slanting position. In the real human arm a number of muscles act at once, and these are attached to the arm at various

parts, and to the bones of the trunk about the shoulder, before and behind. Their power of contraction is very great, and when you young rascals bend the arm to give a blow to another boy who has "cheeked" you, you see a great lump rise near your shoulder, which is the heaping up of a big muscle called the biceps, caused by its contraction.

All our limbs, as well as the head itself, are moved in this way by muscles inserted at various points of the skeleton, enabling us to perform all the mechanical functions necessary to life. A muscle is composed of fleshy fibres, which are combined at the ends into a stringy or wiry substance called tendon. Where there is not much of the fleshy part, you may see these tendons looking almost like small bones—as, for instance, at the back of the hand, where they radiate from a common centre at the wrist to the knuckles. And at your heel is a very good example of a strong tendon, called *tendo Achillis*, which, soon becoming very fleshy above, forms the calf of the leg, of which well-developed youngsters are so proud.

So much for our human levers and sources of mechanical power. But in certain cases the direction of motion needs to be changed, while the muscles remain in their normal position; and we come to just such an arrangement as that of the pulley and cord, where a downward

pull at one end is changed into an upward one at the other. We have one special instance of this in the eye. There is a muscle attached to it on one side, which, soon after leaving it, passes through a cartilaginous loop, and then returns at an acute angle to its former direction, and is ultimately attached to a bone of the skull. This muscle is called the superior oblique, and is the most perfect instance of the system of motion by a cord and pulley to be found in the human frame. The actual pulley turning on its axis is indeed wanting, but its place is well supplied by the ring of smoothly-polished cartilage. While speaking of muscular action, I may once again call attention to the difference between the machinery devised by ourselves and the great human machine, that is so fearfully and wonderfully made that its divine creation is manifest in every part. In those which *we* construct, we need to take hold of the rope or lever, or to attach it to some extraneous motive power to give it action; but in man the will suffices as the prime mover, and at once the muscle contracts, and the eye is moved, or the hand lifted, or the leg advanced, and all is done without noise through the vital agency which, for want of a better name, we call "nerve force."

Let us advance a step farther. In all machines comprising parts which move upon each other, such parts require constant lubrication, and to prevent undue friction they are

made as smooth as possible. This is precisely the case in the human machine. Wherever there is a joint, the rubbing surfaces are coated with cartilage, presenting a highly-polished aspect, as may be seen at any time by separating the bones of a leg of mutton; and over this surface there is diffused an oil vulgarly called joint oil, but which medical men term synovial fluid, secreted by the membranes surrounding the joint. This is supplied in moderate quantities only, just sufficing for perfect lubrication of the parts; but if the latter are injured, there is generally either an increase in quantity or the quality is impaired. The liquor is contained in what is called a bursal sac, as we might keep a supply of oil for a shaft in an oil-cup, and this sac often becomes inflamed and enlarged, forming a swelling at the knee-joint known as housemaid's knee, because it is often caused by kneeling to scour floors. In this, as in other cases, the increased supply of synovial fluid is due to the curative process by which nature throws out additional protection to the joint itself, by increasing the lubricating fluid, and thus forming a natural cushion. Eventually, however, serious injury results, causing sometimes a stiff joint.

The human machine I have so far compared with those of wood and metal, as if the latter were rather the pattern of the former; but, as we all know, fingers were not only made before forks, but the bodies of animals

and men preceded by any number of centuries the mechanical contrivances by which labour is abridged. Indeed, if we go forth into the natural world, we shall there find many a valuable model set before us if we use our eyes and minds to discover them. There is, for instance, a necessity sometimes for a joint that will permit ready motion of the adjacent parts in all directions, but which shall, nevertheless, be close and compact. We find our model here in the shoulder-joint, and we apply it under the descriptive title of a "ball-and-socket" joint. There is, first of all, at one end of the bone which forms the shoulder-blade, a shallow cup, lined, as before, with cartilage, and supplied with synovial fluid. Into this fits with great accuracy a spherical knob, also covered with cartilage and as smooth as polished ivory. To keep the two in contact there is a strong cartilage, and the joint is encased in powerful muscles; so that, although the arm may readily be swung about in all directions, the ball will not leave the socket unless the application of undue force wrenches it out, causing the head to slip over the edge of its cup and to tear some of the ligaments. This happens in dislocation, when we say that the shoulder-blade is out of joint. In the ball-and-socket joint used in mechanics, the principle of this is carried out; but instead of the tendons and ligaments, the cup is made to embrace a larger portion

of the ball, so that the latter cannot escape, or, as in pendent gas-chandeliers, the cup is placed with its bottom part downwards, and its centre is cut out. The pipe to which the ball or hemispherical part is attached is then dropped through this central hole, so that the curved parts rest closely together.

In many centuries no substance was discovered at all comparable to the human skin. This, under the microscope, is seen to consist of cells in several layers; but what chiefly concerns us here is that it is an elastic, soft, and yielding substance—waterproof, yet full of pores through which the perspiration passes freely, far more freely than is generally supposed, it being calculated that no less than two or three pounds weight of water are daily exuded through the skin, and that we have not less than twenty-eight miles of tubing through which it passes. This, at any rate, shows the necessity of keeping the pores open by daily ablution, "cold tumbies" being happily much in vogue for the purpose; but probably an occasional Turkish bath, which results in rivers of perspiration, is necessary to maintain the skin in its natural fine condition of elasticity. Now there are many purposes in mechanics and in the departments of natural science in which just such an elastic substance is required, and for which human skins are certainly not available, though, as an experiment, very excellent leather

has been made from this substance. A careful search discovered first of all a tree called *Ficus elastica*, the indiarubber-tree, the juice of which could be run into moulds, and when dry, was found at ordinary temperatures to possess the above qualities. But, unfortunately, in cold weather, indiarubber becomes almost as hard as board, and its elasticity then disappears; otherwise, especially when worked into very thin sheets, it is not at all unlike skin, and is applicable to many purposes in the arts. But an accident discovered the fact, that in conjunction with sulphur stirred into it when in a melted state, indiarubber became equally pliable at all temperatures, and was thence known as vulcanised.

Now this substance is perhaps the most completely comparable to human skin of all materials known to manufacturers, *i.e.*, the skin of a *living* body. It is waterproof, pliable and elastic at all ordinary temperatures, can be worked thick or thin, and is also very durable. Gigantic strides have been made since its discovery in various directions, as it is just the substance that was required for various purposes of trade; and it has proved applicable far beyond what was originally intended to be its use. The first, or almost the first application of it, was the construction of goloshes or overshoes, which were orginally made by pouring liquid caoutchouc, or indiarubber, over a stocking filled with

sand, and this was first done at the spot where the tree grows, by allowing the juice or gum to flow at once over this primitive mould. But these overshoes were very expensive, generally as hard as board, so that until they were laid by the fire to warm thoroughly, it was impossible to put a foot inside them. As to shape! O dandy boys of the present day, we can imagine the scorn and derision which would be shown could we present such to you to wear! Talk about beetle-crushers, boats, portmanteaus—these were veritable canoes, and yet, for want of a good substitute, they found a ready sale. But when the vulcanised rubber was discovered, which can be used as above, or in combination with elastic cloth and other materials, it was at once seen how beautifully applicable it was to the manufacture of overshoes. And all at once these came by thousands into the market from America, of moderate price, good shape, and of all sizes. Indiarubber canoes hid their diminished faces, and were seen no more—being sentenced to the knife of the executioner, who cut them in pieces for the use of artists and schoolboys for erasing pencil-marks.

Any trade list of vulcanised rubber goods will show to what a pitch this trade has grown. Almost every article of daily use is formed of it, for it is found that by properly arranging the proportions of the sulphur and gum, it may be made hard as wood, or soft as the softest

leather. Hence we can buy elastic rings to hold bundles of letters; elastic cord to be devoted to the window-smashing contrivance called a catapult; polished combs to arrange the flowing locks of youth, or the long hair (all her own of course) of the demoiselle; buckets for water, hose for fire-engines, and ten thousand articles tedious to name. So we may have taken a hint from the outer covering of the human frame; but our cherished skins are safe, and though perhaps we may one day be *cremated*, if it should become the fashion, we need not fear that we shall first be *decorticated* to provide elastic membrane, or questionable leather, for the use of survivors.

Recurring again to the mechanism of the human frame, we have the arch and the dome beautifully shown us in the skull, the hollow bones, and also in the ribs and pelvis. The structure of the bones, moreover, teaches us the important lesson of how to combine lightness and strength; and from these, and perhaps also from the hollow stocks of reeds and corn and other plants, we first learned to cast hollow iron pillars, and, if necessary, to strengthen these towards the ends by sharp ridges or ribs, just as we find many of the human bones strengthened in the neighbourhood of the joints. Then, again, in our veins and arteries we have perfect models of elastic tubing for the conveyance of fluids. In the heart and windpipe we find valves

of perfect design and action. Nor is there any part of the human frame which has not, or may not give to the machinist valuable hints in the art of construction, if he will but make use of eye and mind in studying God's handiwork. And although we call this human machine greatest and noblest of all, because it is the abode of that mysterious something which we denominate the "soul," yet nature—the great universe which we see around us—is also such another glorious machine, of equal perfection in the arrangement of all its details, and in their adaptability to the various purposes for which they were designed. Here we have mechanism and architecture wherever we turn the eye; and it is in the volume of nature that the student must ever search to discover each *principle* of these and kindred sciences, as well as their practical application.

The oak in its giant strength, with buttressed trunk, to which each bough is attached, with its spreading base, "*shouldered*," as it might be called, at the point of junction, calculated to resist the strains brought upon every part of it by the winter's storms — the stately poplar, tapering gracefully from base to summit, yielding but resisting, "stooping to conquer"—the waving corn in the harvest-fields, with slender hollow stem supporting its golden ears, heavy with their autumn gifts to thankless man,—these, and such as these, teach us to combine

lightness with stability, pliability with strength. Every scientific fact, it must be remembered, has been gathered from careful observation of nature in her various moods, and upon these is based the mechanical theory of construction, whether of machinery or of buildings. And not only so, but nature, in all probability, suggested in turn to man the great majority of those arts and appliances whereby he has surrounded himself with creature comforts.

The spider and silkworm have given him his earliest lessons in spinning and combining a number of yarns to make a stronger rope or a coarser thread. The caterpillar has shown him how, by such threads crossed and recrossed, he may weave the fabrics of the loom. The tailor-bird has suggested the use of needle and thread to unite such fabrics to supply him with clothing.

The bee, in her economical use of the wax wherewith she raises her many-chambered palace, has taught us how to produce the greatest results with the least possible material. The beaver as a hydraulic engineer, the rabbit and the fox as constructors of tunnels and underground abodes, have originated, in all probability, the idea of penetrating hill and mountain with railways and canals, and in nearly every instance of new inventions and new discoveries the models will be found in nature's storehouse. But we cannot here carry the subject into further detail.

We gladly leave our young readers the interesting task of hunting out for themselves the mechanical examples which our universe furnishes to instruct her zealous students, and we do so the more readily, that in these days of infidelity they may recognise the stamp of the Creator in all His works, and be led to a deeper reverence and love to Him who made all these things, permitting man to use them for his help and comfort, until admitted to a still more glorious universe, where no spot of sin shall sully its perfections or hide its everlasting glories.

THE END.